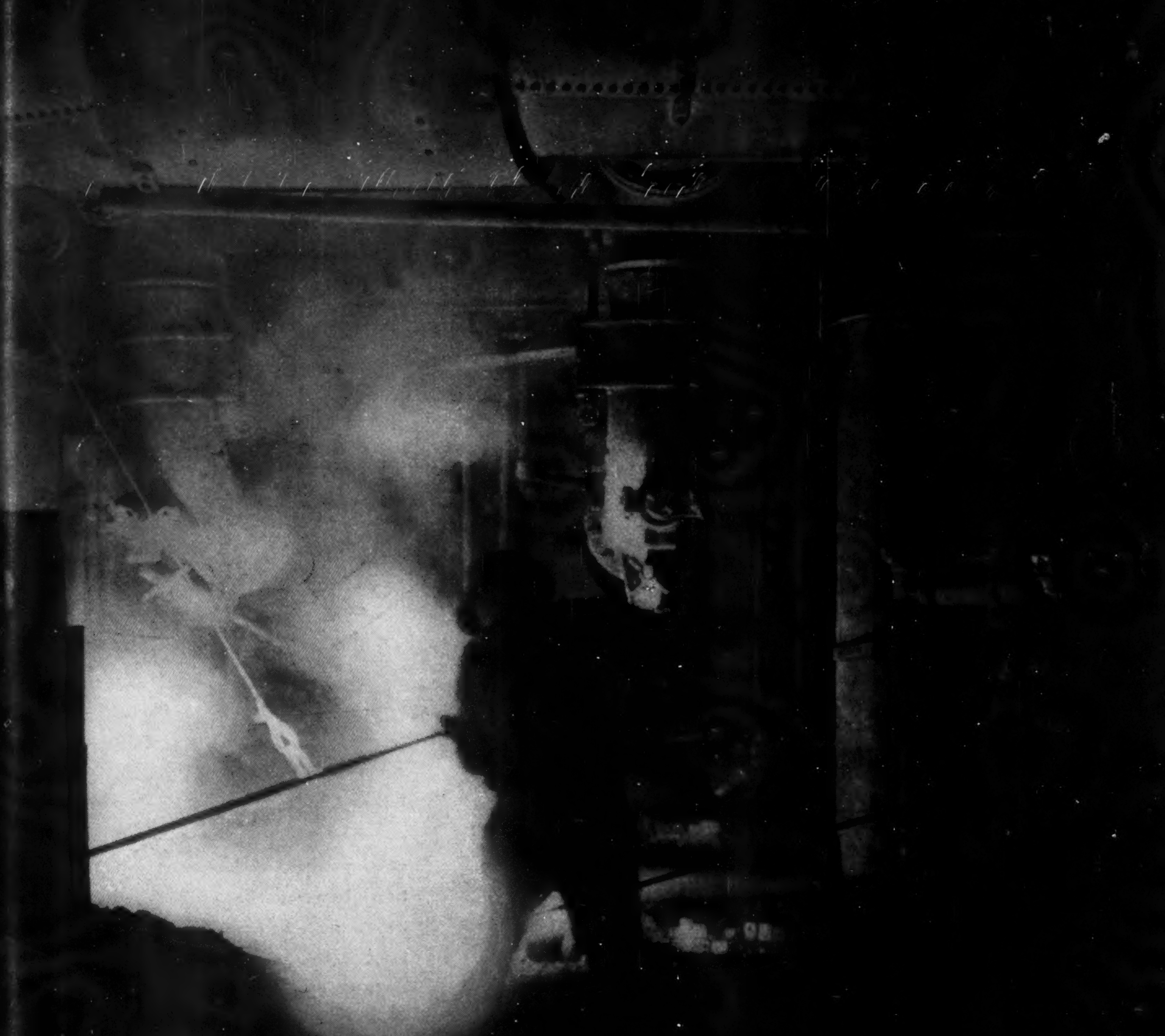
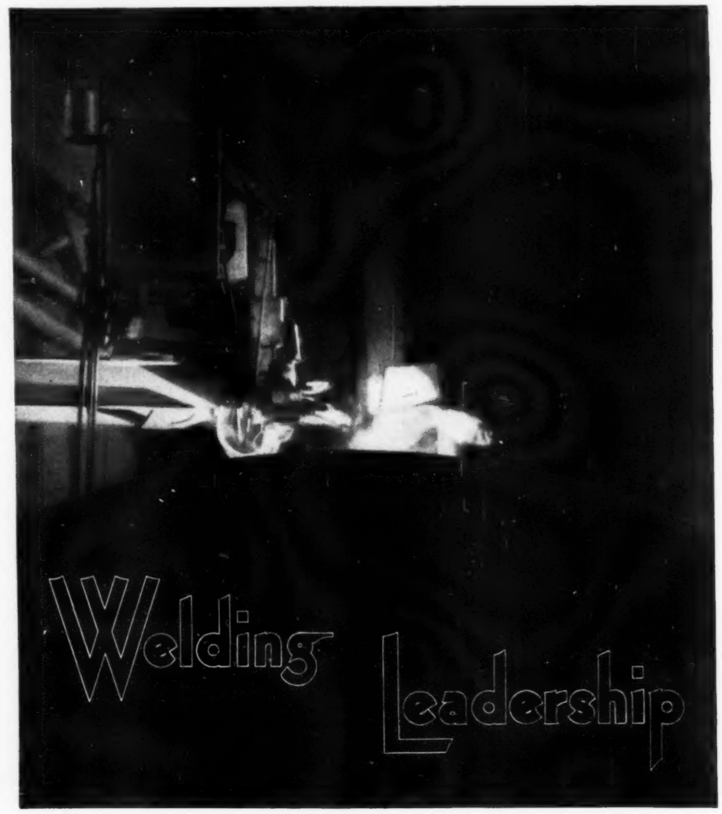
MECHANICAL ENGINEERING



April 1933

400,000 feet of welding in one contract



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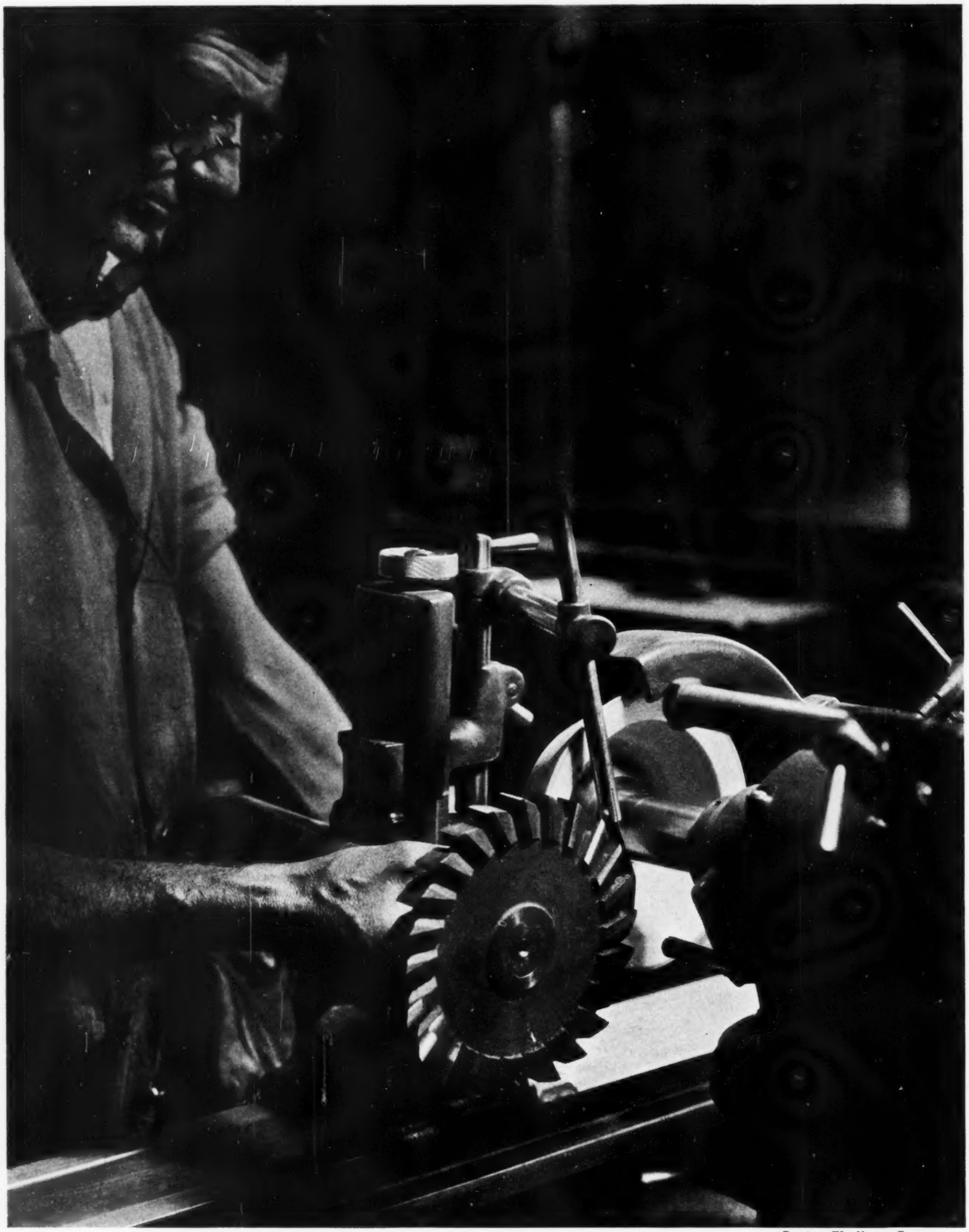

Courtesy The Norton Company

"And Their Desire Is in the Work of Their Craft"

The Balancing of ECONOMIC FORCES[1]

I—An Analysis of Forty Causes of Business Instability

TWO years ago the American Engineering Council assigned to its Committee on the Relation of Consumption, Production, and Distribution this commission:

"The selection and recommendation of such governmental, financial, and business policies as will maintain in the United States a standard of living that is high, broadly distributed, and free from severe fluctuations."

On January 16, 1932, the Committee submitted to the Council its First Progress Report.[2] That report outlined the method of attack which had been adopted, offered a hypothesis as to the occurrence of the existing business recession, and gave an outline of apparent causes which had contributed to that event. It also considered briefly a few of the remedies which had been proposed.

The First Progress Report was approved through letter-ballot of the Assembly early in February, 1932, and released for publication. The Committee, acting under this approval and authorization, released the report to the technical and general press. It was widely distributed and freely commented upon in publications throughout the United States.

The two most constructive results obtained from the distribution of the First Progress Report are: (1) A collection of over two

[1] Second progress report submitted January 13, 1933, to the American Engineering Council by its Committee on the Relation of Consumption, Production, and Distribution. Part II of the report, in which an analysis of 23 out of more than 50 plans and programs submitted for remedying business instability is presented, will be published in the May issue.

[2] Published in MECHANICAL ENGINEERING, June, 1932, pp. 415-423.

From an analysis of 40 alleged causes of business recession, grouped variously as psychological, technological, business-performance, savings and investment, financial, agricultural, and governmental causes, with respect to (*a*) business stability, (*b*) scale of living, and (*c*) distribution of goods, it would appear that—

Psychological causes, while generally classed as contributory, may, in certain stages of the business cycle, be considered as primary in the effects they produce.

The instability of sales, service, luxury- and capital-goods operations is certainly a contributing and perhaps a primary factor in all the elements of economic maladjustment.

As productive processes become more mechanized, more efficient, and less dependent on direct labor, dependence on the rewards for productive operations as the primary means of distributing goods becomes less automatic and certain.

Assuming that the illness of business as a whole is merely the sum of the ills of its parts, leads to remedies affecting individual industries, trade associations, etc. Many of these appear useful and desirable, but there is good reason for questioning such an assumption.

Inequality of wealth in itself is not so determinative as the way in which it is used, whether in consumption, social expenditures, physical investment, or speculation. An unrestrained profit system works most effectively in virgin territory with undeveloped resources, or, less certainly, when rapid technological advantages require new investment. Secular changes in these elements, in world industrialization, and in population growth will severely tax the profit mechanism in its present form.

While the business and profits, and savings and investment factors, set the stage, credit inflation furnishes the energy for destructive speculation, and unwise banking weakens the financial structure and broadens the collapse.

Agriculture is a preponderating factor in the market for goods, and its well-being is vital to national prosperity. However, it is inherently unstable, and further, because of its peculiar exposure to the evils resulting from war financing and war production policies, it is in a situation of distress which is a primary cause of the lowering of the attainable standard of living, and in the whole distribution of wealth.

Tariffs, governmental restraint of business, taxation, and public construction bring serious forces to bear on the economic problem, but in so diverse a way that it is not possible to evaluate them.

From its study of alleged causes here summarized the single finding which the American Engineering Council's Committee is willing to support at this time is that no one all-conclusive cause can be designated as the forerunner of business recession.

The Committee's assay of 23 plans, programs, and remedies will be presented next month.

hundred reviews, in many cases including extensive discussions, offered by eminent men engaged in a wide range of business and professional activities; and (2) a file of more than fifty suggested remedial plans.

These reviews, comprising criticisms, comments, and suggestions, and the proposed plans for business stability, have been of major assistance to the Committee in preparing this Second Progress Report. For all this assistance, so generously and constructively offered, the Committee is deeply appreciative; and it takes this opportunity to acknowledge its indebtedness and to express its gratitude.

This Second Progress Report is divided into two parts:

I An analysis of 40 alleged causes of business instability, classified as primary, contributory, incidental, or doubtful.

II An analysis of the theories, principles, and methods of a selected group of 23 plans offered to prevent or to minimize the effects of business recession. (This part will appear in the May issue.)

I—AN ANALYSIS OF 40 CAUSES OF BUSINESS INSTABILITY

The method of analysis of the alleged causes of business recession which was adopted was suggested by the problem assigned to the Committee as stated in these three questions: What can be done to bring about

(*a*) A decrease in the violence of the fluctuations in the volume of goods produced and consumed, that is, an increase in stability?

(*b*) An increase in the average rate of production and consumption, that is, a rise in the general scale of living?

(*c*) A wider distribution of goods produced?

(*a*) *Business Stability.* The Committee does not believe that perfect stability, or a near approach to it, is possible of attainment. Nor is the Committee even sure that such a state is a desirable objective, for there appear to be creative and rejuvenating forces in moderate, rhythmical variations in the volume of business. However, the present degree of variation is destructive, and must be brought under such a measure of control as will insure the safety of our social structure.

(*b*) *Scale of Living.* A rise in the scale of living is physically possible of attainment to a degree little comprehended by those unfamiliar with the available productive mechanisms, processes, and organizations. Except in occasional and unimportant instances these were not operating to their capacity during the peak of the last boom. The scale of living made possible by existing facilities and which is within easy reach, is that resulting from maximum production and not the mean of the variations of production.

(*c*) *Distribution of Goods.* A wider and larger distribution of goods produced is in one respect a problem in social justice. However, it is here considered as an economic circumstance. The Committee believes that a better distribution—that is, more to classes now enjoying few or almost no goods—is physically attainable without any substantial diminution in the share now obtained by those rendering useful services. The larger share of the possible increases in production should go to those who are able and willing to work, but who are now poorly served by the social mechanism.

In this connection attention is called to the lack of purchasing power of those having very small incomes, as agricultural workers, soft-coal miners, and others, and those whose wages are now at, or close to, predepression levels, as building-trades workers, anthracite miners, and railroad employees. The inability of those groups lacking purchasing power to procure a sufficient volume of the necessities and comforts of life presents a problem, not only of the current depression, but of continuing business operation.

LIMITATIONS OF THIS REPORT

This report does not deal directly with questions of morals or of esthetics. The findings contained herein were not determined by abstract concepts of social justice, nor from the nature of human satisfactions. The Committee took for granted that production and consumption should be less violent in their fluctuations, higher in their average amounts, and more evenly distributed. A self-imposed limitation was established that the problem assigned be studied as a national and not as an international question. While the Committee has taken into account numerous international factors which affect the domestic problem, it has not sought to lay the foundation for international solutions.

There is good reason for this decision; while certain elements of the economic problem are world-wide, other ruling factors are purely national. The problem in the United States is simple in contrast with that in other nations. Here population is not pressing on subsistence. Our national prosperity need not be dependent on the export of a substantial part of our total production. We need not divert our energies to the development of virgin resources, nor to the building up of manufacturing equipment. We are not divided into hostile political segments, but form one country, large in extent, varied and ample in natural resources and in the capacities and abilities of the people.

The assignment definitely limited the investigation to the long-time problem; no consideration was to be given in the first instance to emergency measures.

ALLEGED CAUSES OF INSTABILITY

Numerous causes for economic instability have been alleged. A knowledge and evaluation of them is essential to an understanding of the problem with which the Committee is dealing. The Committee has grouped into seven general classes all alleged causes which have come to its attention. These classes are: Psychological, technological, business performance, savings and investment, financial, agricultural, and governmental. Each alleged cause has been analyzed for the purpose of determining whether it had a primary, contributory, incidental, or doubtful effect upon (*a*) busi-

ness stability, (*b*) scale of living, and (*c*) inequality of distribution.

PSYCHOLOGICAL CAUSES

(1) It has been contended that the instability of business is primarily due to successions of *states of mind*. It is true that at times the business world is activated by a contagious hopefulness, then by speculation, then by fear, and finally by a lethargy of despair. This being true, it is probably a potent factor in effecting the various changes in the business cycle. There are reasons for this series of emotions, as will appear in other connections; and there is significance in the mechanisms by which the changes in emotion are effected. Both at the peak of the boom and the bottom of the recession the psychological factors predominate in importance so far as the immediate situation is concerned.

One cause of the inhibiting emotions can be properly singled out for comment. It is the betrayal of trust. Far too many examples in both large and small business operations have become public during the current depression. Such revelations undermine public confidence, foster hoarding, breed suspicion, and unsettle business. No condemnation of such practices can be too severe.

Psychological factors in this analysis are classed as contributory, adversely affecting business stability. At the same time it is recognized that in certain stages of the business cycle certain of such factors may be properly classed as primary in their effect.

TECHNOLOGICAL CAUSES

(2) *Inefficiency in production* resulting in costs so high as to make business unprofitable is charged with being a primary factor in business instability. As a matter of fact, output per man-hour has increased and unit production costs have decreased, that is, efficiency has greatly increased in the manufacture of most staple products during the last decade, yet there has been a severe business depression. Despite these facts there exists a vague feeling that if efficiency can be still further increased and wastes still further reduced, business will be on a firmer basis. This belief is probably due to a confusion in considering the evident advantages for the individual firm in an increase in efficiency with its possible temporary disadvantages in its general effect.

Inefficiency in production must be classed as a contributory cause of business instability and a hindrance to the wider distribution of goods, and as a primary bar to a rise in the scale of living.

(3) *Inefficiency in distribution*, for reasons which will be given under (5), is perhaps dependent upon efficiency in production. It is a doubtful cause of business instability and restriction of distribution, but is a contributory bar to a rise in the scale of living.

(4) *General overproduction* is frequently assigned as a disturbing result of the use of highly efficient machinery. There can be overproduction in special lines, particularly those of inelastic demand, such as staple foodstuffs; but a survey of the scale of living of the majority of workers dispels the idea that there has been general overproduction. As a cause of business recession, general overproduction, must therefore be classed as a highly doubtful influence.

(5) *Technological unemployment* is claimed to accompany general overproduction. It is also claimed that improved efficiency in production displaces workers while increasing output. Apparently the assumption is that more is made, while purchasing power is not increased, or is even decreased. The answers to this point of view are two:

The first is that improved efficiency will result in a lowered price to the consumer, or an increased profit to the producer, or both. In the first instance consumption will be increased by the lowered price, and in the second the producer's profits will be expended in increased consumption, or the purchase of new capital goods. Doubts as to the beneficial effects of these processes are raised under (19), (20), and (21).

The second answer is that new processes, new occupations, and the various services required by new inventions, reemploy those displaced. There is evidence to support this point of view. Competent investigators have analyzed employment statistics and have found that there has been a steady net increase in the percentage of total population gainfully employed. This conclusion, however, even if entirely correct, is not reassuring. An accepted estimate places the unemployables in our country at some 1,500,000. The best that can be shown for the boom years is that unemployment did not greatly increase. At no time since the World War has there been a general dearth of labor, either skilled or unskilled. When the details of the process of finding new jobs are observed, as described under (6), the reemployment situation is doubly dubious.

Technological unemployment is a possible though doubtful unfavorable primary factor in its influence on stability, scale of living, and distribution. Its contributory effects are not subject to question.

(6) *Instability of Occupation.* Manufacturers have observed with dismay that improved efficiency in production is not easily translated into lower prices or higher profits. The concurrent growth in selling expense has frequently canceled the improvement in manufacturing cost. There is a growing suspicion that the two tendencies are not separate but are connected, perhaps in the following way:

When men are displaced either by machines or by more efficient selling, they tend to obtain reemployment in selling in one of two typical ways: they engage in house-to-house selling, or open service establishments—unneeded gas stations, for instance; or they may be employed by a manufacturer who is expanding his sales department under the pressure of necessity for output [see (8)]. An aspect of the latter situation is the need of educating the public to choose intelligently from among the great variety of manufactured articles offered, a process requiring more men in selling. In either case the reengaged worker is employed under more hazardous conditions than are those who remain in production

activities—particularly those producing the staples of subsistence. Here is a probable element of unbalance, but also an undesirable, although effective, way of maintaining a connection with the economic machine for large numbers who might otherwise be cast off.

There are other sources of occupational instability. As a result of improvements in production, a continuously smaller percentage of workers is concerned with the making of the more stable staples, while a growing percentage is dependent on the fluctuating demand for articles of taste and luxury. The production and distribution of necessities maintain only subsistence levels, while the avenue of business expansion is through the provision of luxury commodities and services. Except for its unbalancing effect this process is desirable; no solution of economic ills which decreases the distribution of constructive luxuries will serve. Our mechanical development is capable of furnishing articles of taste and luxury in large volume and variety, and mechanisms must be devised to permit their unobstructed flow into consumption.

Another variety of occupational instability is that concerned with the manufacture of capital goods—machinery, manufacturing and business buildings, engineering structures, etc. These industries, for obvious reasons, get the full impact due to the variations of the business cycle. It has been shown that the entire drop in consumption for the years 1930 and 1931 might be accounted for by the decrease in capital goods produced and in consumer goods used by those dependent on capital-goods production. This has importance in connection with (20) and (21).

The instability of sales, service, luxury- and capital-goods operations is certainly a contributory and perhaps a primary factor in all the elements of economic maladjustment.

(7) *The shift from agriculture to industry* remains the major factor in occupational instability. Except for floods, freezes, insect pests, and droughts, agriculture on the subsistence basis is a relatively safe occupation. On the whole it provides only a low scale of living. Workers are attracted from this low-scale, stable occupation in agriculture during periods of good business to unstable marginal occupations in industry. This shift is always present when the standard of living is rising. Were general business reasonably stabilized, this change would be desirable as adding both to the market for and production of manufactured goods, thus being a primary factor in advancing the scale of living and giving a more general distribution of wealth. But the existing instability of business acts with particular sensitiveness on these transplanted workers. Therefore the shift from agriculture to industry is a contributory cause of business instability.

(8) *The reduction of profits at reduced plant output* is greater when modern methods are employed, hence lowered output becomes an important cause of general business instability. Under modern operating conditions mechanical devices replace men in productive processes. As a result capital charges are a large proportion of manufacturing cost at full output, and these charges are constant and independent of the volume of output. The charges due to direct materials and labor are small in comparison, and do vary with the volume of output. In contrast, under older methods in industry capital charges were small, and direct labor was the largest item in manufacturing cost. Under these conditions as output decreased, the labor charge, an important proportion of cost, decreased in proportion.[3]

(9) *Unstable relations between price and supply of goods* appear in a highly mechanized industrial economy. That is, the response of output to price changes is sluggish under modern methods where fixed charges are a relatively high proportion of cost.

This situation is made clear by a consideration of the theoretical extremes. If the whole cost was made up of the variable item wages, it would become unprofitable to operate so soon as the selling price dropped to the level of the cost. On the other hand, if the whole cost was made up of the non-variable item of fixed charges, operation would be justified at any selling price. In this situation a low price that entails a loss is still a smaller loss than if the plant were shut down. Hence when fixed charges are high, as they are under modern methods of industrial operation, a reduction in selling price of product does not necessarily cause a shutdown of even the least efficient plants.[4]

From the foregoing considerations it would appear that the modern condition of heavy fixed charges is a primary source of business instability, without any apparent compensations.

(10) *The substitution of power for human effort* is believed by some to be a primary source of unbalance. Careful study of this viewpoint does not reveal important influences not previously considered under (4) to (9), inclusive. The substitution of mechanisms, the transfer of human skill to machinery and tools, rather than the increased amount of power applied, is the essential change. The elements of quantitative importance are the increase in fixed as compared with variable factors in the total cost of output, and the released man-hours due to increased productivity, the latter constituting the crux of the problem of technological balance. The substitution of mechanical power for man-power is a favorable primary factor in raising the general scale of living.

Certain *general considerations* apply to factors (4) to (10), inclusive. As productive processes become more mechanized, more efficient, and less dependent on direct labor, dependence on the rewards for productive operations as the primary means of distributing goods becomes less automatic and certain. There are perhaps other factors and relationships concealed within this situation which have not been isolated. The subject is of the utmost importance.

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[3] These conditions are illustrated in Figs. 1 and 2 of an article by Ralph E. Flanders, entitled "The Economics of Machine Construction," in MECHANICAL ENGINEERING, September, 1932, pp. 605–612.

[4] These relationships are shown in Figs. 3 and 4 of Mr. Flanders' article, above cited.

BUSINESS-PERFORMANCE CAUSES

(11) *Failure of profits to appear at the height of a boom* is the traditional cause for the collapse assigned by some of those who hold to the view that the disturbing causes are primarily due to credit inflation—see (26) and (27). The subject is considered at this point because of its relations with the preceding discussion of technological factors.

Modern productive processes tend to develop profits rapidly as production increases up to the point of diminishing returns. This tendency can be blocked by labor scarcity and consequent high labor costs due to high wages and overtime, by inefficient, marginal labor, and by scarcity of materials. However none of these influences appeared in 1929 in any important class of goods. Prices generally tended downward, indicating an increased difficulty in disposing of output. The only expense element tending to increase was that of selling, for reasons presented under (3), (6), and (8). The reports of taxable incomes for the boom years give no indication of an increasing difficulty during that period in making profits from business and speculative transactions as a whole.

Lack of profit is a factor of doubtful importance as affecting any element of the present business cycle. Fear of the lack of opportunity for making profit, however, has an unstabilizing influence as it precipitates business inactivity.

(12) *False views as to the possibility of continuous profits* affect business procedure adversely. In particular, there has been a tendency to consider net earnings of the most profitable period as being normal, and to pay them out in dividends on that assumption. Only in recent years has it become customary to adjust current policy to the movements of the cycle as a whole, recognizing that each industry has its characteristic history during the course of any cycle of business.

A full view of the business cycle would suggest the need of reserves for dividends in poor times for wages and salaries to maintain the organization, for unemployment funds, for the development work and plant improvement which can be carried on most advantageously during depression, and for working capital when business again appears.

To the extent that a business does not set up such reserves its operations become more unsteady and subject to wider fluctuations. If business in general follows this course, the total effect is to magnify the variations. This false view of continuing profits is a contributory cause of business instability.

(13) *Natural rhythms in the operating performance of individual industries* can be detected. When these chance to coincide in their maximum or minimum phases, the total volume of business is affected thereby.

This characteristic has been studied for four major industries: food, automobiles, textiles, and building construction. Of these, all except food exhibit marked rhythms, based on replacement periods. Furthermore these rhythms appeared to culminate synchronously in the events of 1929–30.

In view of all the other effective influences it is difficult to see how the natural rhythms of industry can do more than determine the timing of the cycle and affect its amplitude. They cannot be charged with a major responsibility for its occurrence. They are classed as an incidental factor affecting business stability.

(14) *Unbalanced relations between different branches of industry* have been declared by some authorities to be the chief cause of business instability. As a major example the disturbed balance between agriculture and manufacturing has been cited.

This factor is uncertain as a primary cause. Analysis at once turns to discovering the reasons for the disturbance of relationship. Several elements have been cited which upset the traditional corrective reactions of price, profit, and production, of supply and demand. The special factors depressing agriculture are discussed in (33) to (36). Except for agriculture this factor is at the most contributory. Its presentation even is a description of a situation rather than a statement of cause and effect.

(15) *Attempts at price fixing and production control*, private and governmental, are believed by some to have upset the natural economic compensations. Wheat and cotton stabilization, coffee, copper, and sugar control, the prorating of petroleum production, all are looked upon as introducing rigidity into an organism whose successful functioning depends upon flexibility and responsiveness.

There is no doubt as to the ultimate harmfulness of some of these projects, and all of them have dubious aspects. In general, rigid production control in this country, in commodities naturally or artificially protected from world competition, will lead inevitably to governmental price control. There is therefore great need for examining the practical effect of price control. There is little that is encouraging in its history. It appears to be most justifiable in the case of unreplaceable, natural resources, and only partly successful in the case of the major staples, as demonstrated by the checkered history of the continental cartels.

An example from current experience is afforded by copper in the United States. The price was fixed at 18 cents per pound. As results, overproduction of the metal and excessive speculation in stocks of the producing companies were encouraged, and substitutes for copper were freely adopted. Consumption decreased and the industry became demoralized. The price of the metal dropped to 5 cents per pound.

Attempts at price fixing and production control, if not a primary cause of business instability, are a major contributory influence in the industries where they are practiced.

(16) *Excessive size of industrial organizations* is claimed to be a specific cause of general business unbalance. It is asserted that the ability required to aggregate or consolidate a great unit of production and distribution is much less than that needed to operate it properly after it has been assembled.

This is a reasonable assumption, and is supported by

the present tendency toward dissolution and decentralization in many large industries, in the difficulties which many mergers have found in making expected savings, and in the present-day realistic attitude toward the profit possibilities involved.

However, it is difficult to see how the history of the late boom and the present depression would have been greatly different if the largest industrial units had been smaller in size. There might have been a less painful history if there had not been a general opinion favorable to mergers which made stocks of holding companies and similar securities acceptable to investors and speculators. That aspect is discussed under (23) and (24).

The great size of industrial units is a doubtful causal factor in business instability, but it does affect the severity of depressions.

The viewpoint which gives importance to the items under (11) to (16), inclusive, demands attention. The basic assumption is that the illness of business as a whole is merely the sum of the ills of its parts. This assumption leads to remedies affecting individual industries, trade associations, etc. Many of these remedies appear to be useful and desirable but there is good reason for questioning the basic assumption. This point of view is developed under the headings immediately following.

CAUSES RELATING TO SAVINGS AND INVESTMENT

(17) *Inequality in the distribution of wealth* is often advanced as a factor affecting business stability and the scale of living. The contention is that the failure to control the distribution of the standard of living reacts unfavorably on its degree and its stability, besides being undesirable in itself.

Those who specially hold this viewpoint are usually disturbed with the manner in which wealth is accumulated, as well as with its total volume.

Lending for interest has often been attacked, and also, more recently, profit, as distinguished from payment under free competition for personal services.

So far as these contentions are based on concepts of justice, they are outside the province of this report. Their presentation here is concerned with their effect on business stability and the general scale of living. See (18) following.

(18) *Private ownership of natural resources*, or of artificial monopolies, was the particular concern of Henry George. He questioned the justice and wisdom of permitting such ownership, whether of mineral deposits, fertility and site value, or franchises. He contended that the owner was permitted to exact rent from the community through his ability to withhold such resources from use, rather than from the rendering of actual service; and, in addition, that any increase in productive activity by his neighbors enabled him to increase his returns without effort on his part.

It is apparent that the most unjust types of social organization are not necessarily unstable. For conditions to which it is economically adapted, slavery is stable as an institution and permits a stabilized rate of production and consumption. The same may be said of robbery even, at least in such institutionalized forms as that enjoyed by the medieval barons of the Rhine.

Under more civilized conditions it does not necessarily clog the economic processes to have large accumulations of wealth. If the few large recipients actually spend their income as freely as would a larger number of small recipients totaling the same income, the impersonal objectives of the economic process are served, even though human ends are neglected. In particular if large sums are thus disbursed for personal service—servants, gardeners, chauffeurs, grooms, yacht crews, and the like, the rich act as distributing channels for the social income.[5] As is indicated under (19) and (20), there is more question of the effects of the savings and investments of the wealthy than of their expenditures.

The effect of concentrated income, as such, on stability seems to be doubtful. The retaining of workers for personal service, if they are withdrawn from industry when there needed, affects the general scale of living adversely. If they are recruited from those otherwise unemployed, the effect on both the scale of living and distribution of wealth would seem to be favorable, though incidental.

(19) *Oversaving* has been urged as the primary cause of business instability. Briefly the theory is this:

In times when industry and commerce as a whole are operating on an even keel, neither expanding nor contracting, and neither adding to nor drawing on their surpluses, the acts of extraction, manufacture, and distribution of goods finance their purchase by the general public. The receipts from the monthly sales are all paid out in wages, salaries, and dividends, for materials and supplies, repair and replacement of equipment, taxes, insurance, and other services. If the firms and individuals to whom these sums are paid are likewise neither saving nor drawing on savings, but spending all they receive, the whole process is completely self-supporting. This is a commonplace of classic economics. Furthermore, expansion of activity can take place without upsetting the balance, which may thus be dynamic rather than static. For if, instead of paying out dividends, a company finds it expedient to spend its profits in expanding its plant and making additional expenditures for more material and increased labor for a larger work-in-process account, the increased expenditures go into the general pool of purchasing power to finance the initial purchase of the increased output, which then balances as before, but at a higher level. All this of course supposes that the product is salable and that increased labor hours are available. These are purely ideal conditions.

Many departures from ideal conditions come to mind. The most serious of them is the necessity for saving. Sad experience in an uncertain world has taught firms and individuals that they must save if they are to survive. But the act of saving withholds immediate purchasing power so that society, to the extent of its aggregate saving, does not buy the goods it has made.

[5] For a contrary view, but based largely on ethical grounds, see Thorstein Veblen's "Theory of the Leisure Classes."

These statements require qualification. The amount of "money," and the purchasing power which it represents, are not fixed, but variable. See particularly (26), (27), (29), and (30). Money varies both in nominal amount and in purchasing power per unit with the activities of the Federal Reserve Banks; and in the form of "credit" it is expanded every time a bank makes a loan, and is contracted when the loan is repaid.

Another qualification, and an even more important one, relates to the use made of savings. If savings are not hoarded, but banked, they normally find their way into new investment, and this is their proper use. If this takes place, they are ultimately used to buy materials and equipment and to pay wages. When so used, they restore the balance of purchasing power. In this case the only harmful effect is in the time lag between saving and investment, which is minimized by the banking mechanism. As savings increase in amount, their rate of inflow may be conceivably too great for the outlets furnished by obviously profitable investment, as described under (20) and (21). Uninvestable savings would then build up. This increase would aggravate the difficulty of selling the goods made.

The correctness of this theory, as concerns the present depression, hinges on two points. As a matter of fact, was there any failure in purchasing power previous to the collapse of September, 1929? As a matter of theory or fact, is it possible for funds which have been banked and thereafter loaned out for any purposes whatsoever to escape an ultimate use in the purchase of goods and services of some sort?

In answer to the first question, reference is made to the index of Volume of Manufacturing Production as determined by the Federal Reserve Board. Production fell off in May, 1929, largely due to the drop in automobile output. Other industries did not follow until August and September. That the drop in output was not compensated for by a rise in prices is shown by the Index of the U. S. Bureau of Labor Statistics. The peak of prices occurred in 1928, with a rapid drop commencing in 1929, about the time of the drop in production. The coincident drop in price and volume points toward an increased difficulty in disposing of output and is favorable to the oversaving theory.

On the other hand, it is not so clear that savings entrusted to banks can escape use in the purchase of goods or services, unless they are held idly in reserves. In 1929 funds were not hoarded, but banked, and loaned by the banks.

In the First Progress Report of this Committee (February, 1932) it was contended that funds loaned on the money market were, in part at least, withdrawn from purchasing power. This contention has been denied by Professor Cassel. The countervailing arguments presented by Professor Eitemann appear to be convincing.

No opinion in regard to this theory is given. The matter is left indeterminate and set apart for further study. Business experience appears to support it. Theoretical analysis makes it appear untenable.

(20) *Overinvestment* would appear to be possible, even if it can be shown that all funds saved find an ultimate destination in the purchase of goods and services. Oversaving may still be effective in the sense that it leads to an undue expansion of productive equipment without generation of a corresponding purchasing power to dispose of the output of that equipment. This theory has been convincingly stated by J. A. Hobson.[6] Business experience and available data tend to support the theory. Funds do appear to have gone unduly into physical investment in plant, office buildings, and hotels before and during the height of the boom, though the strictly productive investment appears to have declined before the peak. See (23). So far as the productive plant is concerned, the overcapacity at the peak of several important industries has been investigated by the U. S. Department of Commerce.[7] These studies indicate that in all major industries there existed at the peak of production an unused capacity varying from 10 to 30 per cent. It cannot be claimed that this unused capacity was the most efficient, but it is clear that at the recent peak, marginal productive capacity was not used to the extent customary in previous booms.

There are, then, evidences of overinvestment or unwise investment in capital facilities as compared with the volume of production which consumers are able or wish to purchase. That it was a question of ability of consumers rather than their desire was argued under (4). It does not clearly appear, however, that this excess productive capacity, resulting from overinvestment, necessarily slows up the flow of business. Why are not the production and sale of capital goods as effective as consumer goods in financing purchasing power? An abandoned automobile or factory seem to be in the same category. Each employed men and materials in its production, and in varying degrees in its later use.

The most evident difference lies in the fact that the now unneeded factory had formerly attracted workers, some from other factories, others from agriculture and the ranks of the unemployed. Industry was unable to sustain these workers, so they were compelled to make new connections or be unemployed. At least, therefore, there is involved a social dislocation which is not easily or quickly adjusted; and during the process of adjustment there is a failure of purchasing power.

It is clear that unneeded capacity lowers the general scale of living. It turns productive activity into impersonally wasteful uses. Overinvestment seems at first sight to be a much more direct and serious cause of economic evil than it proves to be on careful analysis. Possibly there are elements involved which have not been clearly distinguished.

Overinvestment, or unwise investment, is a probable primary cause of instability, and certainly a contributory bar to an increase in the general scale of living. Finally, the resulting destruction of capital is a clumsy and wasteful method of regaining balance.

[6] See, for instance, his "Rationalization and Unemployment Problem." Read also the picturesque and uncompromising pamphlet by David C. Coyle, "Business Vs. Finance," published by the author at 101 Park Avenue, New York City.

[7] See Bulletin of the Taylor Society for June, 1932.

(21) *A slackening in the opportunity for profitable investment* has been suggested as a present or imminent condition either on a temporary or a permanent basis.

The discussion under (18), (19), and (20) indicates the desirability of a balance between savings and profitable investment. That the ratio between the rate of savings and the rate of investment is highly significant is becoming generally recognized.[8] It may be expected that anything which diminishes the opportunity for profitable opportunities for investment will have a harmful effect. Its nature was indicated in connection with fluctuations in the equipment industries discussed under (6).

That there has been a permanent slackening in opportunity for profitable investment is a highly dubious conclusion, but is worthy of thought, nevertheless. An obvious factor is the slackening of population growth, due to the curtailment of immigration and the inevitable flattening of the curve of natural increase. Such a large increase of investment in the future will not be needed to care for increased population.

Another evident factor is the approach to complete development of our natural resources, and the rapid development of competing resources in more recently explored parts of the earth.

Allusion has been made to a serious and significant fact which lends weight to these speculations. This last boom was the first major one in which industry as a whole did not receive orders in excess of its capacity. Deliveries were not greatly delayed at the peak. It was a "buyers' market." For the first time there was ample equipment and labor with which to meet the extreme demands of unrestrained business enthusiasm.

There is one large and hopeful chance for a renewed demand for physical investment. This will become a reality if our economy is recast to provide increased purchasing power for the millions who are able and willing to render effective service, but who either temporarily or permanently cannot secure employment. An important factor in providing this increased purchasing power will be the higher wages which will prevail as soon as it becomes economically sound to pay them.

If overinvestment in enterprises for the production of consumer goods is a factor tending toward business instability and disturbance of the scale of living, any considerable permanent slackening in the opportunity for such investment would have an identical effect.

(22) *Economies through managerial efficiency* are particularly upsetting to the balance between production and purchasing power.

While great changes in production methods took place in the last generation, they were commonly dependent on the development of new and more expensive equipment. This industrial progress furnished a continuing use in investment for the savings derived from that progress. Frederick W. Taylor, who initiated the industrial efficiency movement in the 90's, made full use of the latest improvements in mechanism and apparatus. However, he was particularly concerned with the great efficiencies to be obtained by the rational use of existing mechanisms. His principles have had their most rapid expansion in the last decade, during which time there has been a great increase in efficiency, resulting in corresponding profits. To the extent the profits resulted from improvement or change in management policies, they did not generate an outlet for savings in any corresponding volume of new physical investment.

Improvement in managerial efficiency appears to be a contributory cause of unbalance, a primary beneficial factor in a possible rise in the scale of living, and of doubtful effect on the distribution of wealth.

The factors (17) to (22), relating to the accumulation of savings and their flow into investment, are of great importance. Inequality in wealth in itself is not so determinative as the way in which it is used, whether in consumption, social expenditures, physical investment, or speculation. See (23). Much of the importance in the question hinges on future trends which are not clearly defined. An unrestrained profit system works most effectively in the situation of virgin territory with undeveloped resources, or, with less certainty, when rapid technological advances require new investment. Secular changes in these elements, in world industrialization, and in population growth will severely tax the profit mechanism in its present form.

These factors probably affect stability primarily and adversely, contribute to delay in a rise in the general scale of living, and affect primarily and adversely the distribution of wealth.

FINANCIAL CAUSES

(23) *Speculation* is a commonly assigned cause of business and economic troubles. It is a conspicuous feature in every business boom. Indeed, speculative fever and high business activity are so inseparable that they have tended to become identical from the practical point of view. With regard to this situation, two questions may properly be asked. Business activity and speculation have always gone together, but need they be joined? Is speculation itself a cause of collapse, or only a symptom of more fundamental disorders?

The first question may be resolved into the more basic inquiry as to whether there was anything essentially speculative in the physical volume of business during the years 1928 and 1929. So far as concerns goods for human consumption and enjoyment, this query may be answered unhesitatingly in the negative. There are two ultimate limitations on the economically justifiable production of material goods: The requirements that unreplaceable natural resources must not be squandered, and that enjoyable leisure must not be sacrificed by producing products to be wastefully consumed.

As regards the first limitation, it may be asserted with confidence that, as a whole, our resources are not being squandered. Some are replaceable, others exist in larger quantities than has hitherto been realized, and present or imminent technological advance has relieved the anxiety about others. With appropriate develop-

[8] The two-volume work on "Money," by J. M. Keynes is largely an exposition of this thesis.

ment and conservation there need be no crisis, even on a broader scale of production.

The second limitation, that of leisure versus goods, is primarily a question of values, and so is in part outside the present field of discussion. It may properly be noted, however, that even with business at its best there were millions of American citizens existing on a very low scale of living. See (4). Among those earning so-called "good wages," certain standards, such as housing and furnishing, for instance, were inadequate.

As a whole, the people did not make more goods than could be properly enjoyed, nor were they made on such a scale as to tax unduly our natural resources or the energies of the population.

The second question, whether speculation is a cause or a symptom, is more difficult to analyze.

From the business and industrial point of view the history of the last boom may be stated as follows: The unparalleled improvements in machinery, processes, and management methods in the period since the war resulted in a large increase in productivity of existing manufacturing establishments whose profitable operation encouraged the building of additional plants. For a time the provision of the improved and additional equipment absorbed the large available profits, furnished employment in the production of capital goods in new investment for labor otherwise displaced, and thus offered a market for the increased flow of consumer goods.

As the provision of new equipment approached saturation, however, the situation changed. Increased output was maintained and profits were high, but there had been no proportionately increased returns to labor and to those in the lower-salaried positions during this period of expansion. Nor did those receiving dividends and the higher salaries choose to spend in consumption the full amounts received. They sought further investment instead. There was thus a failure in purchasing power to match the increased production of consumer goods. This situation was masked for a time by the rapid expansion of instalment buying [see (28)], but became evident when its source of credit had been stretched to its limit.

The evident adequacy of existing plants, and the temporarily high returns from their operation, led to a condition in which the purchase of the securities of established enterprises was much more attractive than the building of new ones. This process was stimulated and expanded by the desire to deal in securities as commodities, as something to be bought and sold at a profit. Thus vast accumulations of savings, both large and small, were directed into speculation instead of new investment. This stimulated the real-estate market and the investment-banking business, and led to the floating of immense and valueless issues which represented no physical expansion whatever, but merely revaluation of properties at highly inflated levels, based on expected earnings. Speculation is thus seen to be an almost inevitable result of the assumed oversaving and overinvestment described under (19) and (20).

The speculation, however, did not focus on material goods or on documentary titles to them. Stock and bond prices soared far above the physical equities which they represented. The primary expectation of earning power was based on the expectation of a higher scale of living to match the new productivity. To this extent speculation was a result, not a cause. Its foundation was weakened by the failure to provide directly in wages and salaries for purchasing power. Furthermore, the investment transactions involved soon left their foundation in savings and soared aloft on the flimsy wings of credit inflation. See (27).

Speculation is always latent in our social structure. In its recent outbreak it was, in the first instance, a result of other causes, but it quickly became an enormously exaggerated unbalancing factor on its own account. As such it destroyed business stability.

(24) *Investment banking* has been subjected to much criticism for the part it has played in unsettling business. It is charged with misleading the public through the sale of worthless securities. Its relationships are sufficiently described in the preceding paragraphs. The extent to which responsibility can be placed upon it and accepted by it, or the degree and kind of control which can and should be imposed, are matters relating to remedies rather than causes, and will therefore be left for later consideration.

(25) *Commercial banking policy* in general may be an unstable element. Unfavorable effects may result from policies customary in business and permitted by legislation, or from those forced upon it by governmental regulation. In either event legislative control appears to be a necessary factor, even though at times it may be unwisely applied.

Certain governmental provisions have, or may have, a primary stabilizing effect. Among these are the semi-official functions of the Federal Reserve Banks, which supply credit for business uses [see (26)], inspect operations of all member-banks, and mobilize resources for the support of member-banks during periods in which failures are liable to occur. These provisions, however, apply only to member-banks.

Unfavorable elements of governmental regulation are seen by many in state legislation against branch banking, which tends in some states to foster the growth of weak local institutions in small communities. While hundreds of such banks have failed during the current depression, a number of large institutions have also closed their doors.

Still a third class of governmental effect is seen in the laxity of laws in some states. The operations of banking are too vital to the maintenance of individual and general prosperity, too tempting in their profit possibilities to the inexperienced and to the dishonest, and partake so closely of the nature of a social trust, that they cannot be left open to free competition and initiative, nor are they completely so left in any civilized country.

There are other banking practices of a recognized sort, some optional, others inescapable, which act as elements of unbalance.

Chief among the apparently inescapable factors is the necessity for selling securities by the banks during and after the collapse of a boom to "maintain a liquid position," so that the banks can meet the lawful demands for cash on the part of their depositors. Such selling embarrasses individual borrowers and lowers security prices. Both practices tend to hasten and accentuate the collapse as much as speculation hastens and accentuates the boom.

The most effective act of commercial banking practice is the control of credit, involving the defensive act of contraction—described above in one of its forms—and the more positive acts of expansion and inflation, which are referred to under (26) and (27).

In general, banking policies, whether resulting from the practices of the business or from governmental regulation or its absence, have a serious primary effect on business stability.

(26) *Credit expansion and contraction* is a normal banking function, whose proper and easy performance was the original purpose of the Federal Reserve banking system. Credit expansion actually adds to the funds available to business by the process of making loans. A bank with a satisfactory surplus loans a depositor against commercial paper, credits the paper to itself, and charges the borrower. The latter leaves the funds in his account for a time, but checks them out sooner or later, transferring the funds to other accounts in the same bank or in other banks. But as a whole, to the extent that the account is checked out, other accounts similarly originated in other banks are being checked in, so that the net result is an increase of funds for business without a corresponding decrease in resources for the banks. Since the paper employed is usually of a self-liquidating character, the amounts demanded are paid on the completion of the business transaction which the loans were originally made to finance.

To facilitate this normal process, the Federal Reserve system arranges for the pooling of the reserves of the member-banks, and also for the rediscounting of the paper on which its loans are based. The latter act, in particular, greatly increases the ability of a bank to make loans, as it promptly receives the amount of the principal back from the Federal Reserve bank, as well as enjoys the increased deposits resulting from the loan.

It is evident that the total effect of individual banking policies in making or refusing loans at lower or higher rates has a marked effect on business expansion and contraction. It is furthermore evident that the rediscount rate of the Federal Reserve Bank has a still more fundamental and controllable effect of the same sort.

That this effect is not directly proportional to the numerical values of the pooled reserves or of the discount rate is evident from the present situation. Psychological factors [see (1)], are effective also. Even that more technical branch of economics called finance must be classed as a "social science," with all of the implications which that term comprehends.

Banking policy with reference to credit expansion and contraction has primary effect on the expansion and contraction of business, and thus on its stability. That it is a direct cause of speculation, and maintains that fever after it is generated, is undoubted. That it exaggerates speculation, which itself exaggerates original business instability, likewise seems clear.

(27) *Credit inflation* is a term hitherto applied to credit expansion carried to an extreme. Recently it has been proposed to assign to it a more definite and measurable meaning to distinguish it from normal expansion and contraction.[9]

In considering these concepts, it should be borne in mind that the short-term loans, discussed in (26), usually reappear in checking accounts. To the extent that business operations are financed by such self-liquidating loans, these two elements should tend to balance each other, or at least to rise and fall with a measurably consistent difference, considering the operation of banking as a whole. It is likewise asserted that the time deposits of all banks—which represent savings—should show an equality with the long-time paper, mortgages, stocks, bonds, and the like. This is a reappearance, from a new angle, of the principle that savings should equal investment, which is briefly treated under (19) and (20). It is more fully discussed in Keynes's treatise on money.

According to older viewpoints—here Keynes must be included—credit expansion and contraction are relative factors. All bank loaning operations represent its existence in some degree, and it would never sink to zero except on the extinction of all business not done on a barter or gold basis. The reason for the existence of the banking system would vanish with its extinction.

Harwood contends that it is desirable to keep credit expansion based on investment-type assets as near zero as possible. When so kept it would appear that: (*a*) the rate of saving is equal to the rate of investment, i.e., investments are just absorbing savings; (*b*) there is no debt structure being built up on overvalued assets to become top-heavy and later crash and require painful liquidation; (*c*) speculative profits and losses are currently wiping each other out, leaving the returns from industry to be distributed more nearly on the basis of competitive reward for services rendered, whether by management, labor, or capital;[10] (*d*) the general price level would permanently adjust itself to the slowly changing gold level, undisturbed by credit inflation; and (*e*) the growth of security prices would be a measure of the actual saving of physical goods and their application to physical investment. Under present conditions the increase in values represents principally the inflation of funds available for their purchase.

In this view, any cumulative excess of investment over savings is a fallacious and an unstable condition, self-generative of further inflation, and only to be

[9] See particularly "Cause and Control of the Business Cycle," by E. C. Harwood, Financial Publishing Company, New York, N. Y.

[10] The return to capital will approximate the "natural rate" of interest. There would seem to be no effect on the returns from natural and artificial monopolies, discussed under (18).

arrested by its approach to the limit of gold reserves, as in 1920, or by a general recognition of its top-heaviness, as in 1919.

While the general position taken by Harwood seems to be useful, his statistical work has been criticized. Credit inflation is one of the first factors affecting business stability which needs control. It cannot be maintained, however, that it is the only cause of business instability.

(28) *Instalment buying* is classed among the financial causes because on any large scale it depends ultimately on the extension of banking support through credit corporations or otherwise. The crucial aspect is the method of financing. If bank credit is employed, it may be unfortunate in its effects, for it provides purchasing power that has neither been earned nor saved. If, however, the credit represents savings, the situation may be sound.

In this analysis [see (23)], it appears as an indication of maldistribution of purchasing power, of a diversion of an undue proportion of the returns of industry from the purchase of consumer goods. Its application to the purchase of capital goods is of considerable proportions.

Its expansion, as inflation approaches its climax, appears as an exaggerating effect on unbalance. It conceals the deficiency in purchasing power for consumer goods, maintains an appearance of stability when foundations are seriously impaired, makes the collapse more serious, and delays recovery by requiring consumers to pay for past purchases before they can apply earnings in full to the purchase of current consumption.

It is a primary factor in delaying the return to stability, with no apparent permanent effects on the scale of living or equality of distribution.

(29) *Monetary factors* are of evident importance in economic disturbances. They manifest themselves through variations in the general price level, that is, through changes in the value of the dollar. These changes are due in part to the factor of credit inflation and deflation, already described, and in part to the relative value of gold on which our currency is based.

While no technical description of the theory of prices, on which experts disagree, is given, it is still clear that prices must be some function of the total funds available, and that these funds are composed of credit in various forms, on the one hand, and of currency, on the other. The currency is for the most part gold-based. Credit is gold-limited, but not gold-based.

A part of the difficulty surrounding the subject arises from the fact that the factors of currency and credit have not been separated, and that there are differences of opinion as to the nature of the credit factor.

There is no dispute as to the seriousness of extreme variations in the price level. As the level rises, persons with fixed incomes suffer hardship, creditors are paid in money of lower purchasing power than that which they lent, and wages tend to lag behind prices, though employment is good. On the decline, debtors find it hard or even impossible to pay in costly dollars debts incurred during inflation. On the other hand, creditors who are paid gain thereby, those with fixed incomes enjoy an advantage for a time and prices tend to fall faster than wages, though employment is scarce.

On the whole, the variation in the price level tends to enrich the more astute of the investing class, who are accustomed to reckon on and adjust themselves to its variations. In its extreme variations, as in the drop of 1920–21, and again from 1929 to the present, the creditor class becomes involved in the distresses of the debtors and no one profits.

If credit inflation could be controlled, and the price level maintained by the relationship between the productive costs of gold as a commodity and other commodities, changes in the price level would not be as serious as they are now. The prime advantage of gold as a currency base lies in the large volume of permanent monetary supply as compared with annual accretions. Price fluctuations based on this factor alone would therefore probably be of such slow effect that all classes of society could adjust themselves to it without hardship.

The monetary factor is a primary cause of business instability, and a contributory cause of an unsatisfactory scale of living and of inequality in distribution.

(30) *War inflation* is by all odds the most serious form of monetary disturbance. It is primarily a credit factor, and only secondarily a gold phenomenon. No great war has been financed without credit inflation, and until some other way is found there is a grave question as to whether the distresses of the succeeding deflation do not in their sum exceed the physical and spiritual miseries of the armed conflict.

If we would avoid this greatest cause of instability, of scales of living reduced below the attainable standards, and of unfortunate spreads in the distribution of wealth, war must be prevented with its accompanying inflation and its inevitable deflation.

(31) *The burden of debt* is a factor whose effect is obvious and directly felt, but whose elements are more numerous than appear at first sight. The total of public and private debt in the United States is enormous; a recent estimate places the total of industrial indebtedness (bonds, mortgages, bank loans, etc.) at over $200,000,000,000. While such sums are very great, their significance can be exaggerated. In substance, they state the total of a certain form of evidence of ownership, the property itself being under the management of others than the owners with the expectation that they can "service the loans" (pay interest and pay instalments on the purchase of the property) and still have something left over.

This situation might not be unmanageable except as the change in the value of the dollar makes it so. Most of these obligations were undertaken at a much higher price level. It is the variation in the monetary factor which makes the burden unendurable.

Indebtedness under these conditions has one effect of its own as well. It makes it difficult or impossible to come to a profit basis during a depression by reducing wages, salaries, and other variable expenses. The com-

pelling reason for these reductions is to make operation less difficult. This has been indicated under (8). The burden of debt is an important element of fixed expenses in many industries.

In general, the burden of debt has the same effects as deflation under the monetary factor. See (29).

(32) *Foreign debts* are a disturbing factor, whether in the operations by which they are incurred, their continued existence, or the attempts made to service and collect them. But their effects appear to be different from purely domestic ones, in that they operate through the mechanism of international exchange, and affect or are affected by direct political considerations.

The normal difficulties of war-debt payment have been accentuated by the drop in the price level, the same as for private domestic debts. Nations as well as individuals have bound themselves to pay in dear money obligations which were incurred in cheap money. This is reflected in part by drops in exchange value of those nations which have gone off the gold standard.

The difficulties of repayment are partly political and partly economic, aside from the change in values. We have no mechanism for receiving large payments. We cannot be paid in gold, we are unwilling to receive the equivalent in an excess of imports on account of its effect on domestic industry, and foreign credits or even currency are useless except as they can be exchanged for gold or goods, or absorbed into the "invisible items" of the international balance sheet. This subject is only touched upon; here the concern is primarily with domestic questions.

There is no doubt that the collapse of the European financial structure in 1931, after this country had made unwise loans to support it, had a serious effect on our own condition and possibilities of recovery.

During the war we loaned our allies goods, primarily, taking paper in return. In the periods since the war our net export of goods has tended to vary with our net export of capital. Fundamentally this means that the producers of exported goods are paid by the domestic buyers of foreign loans. Viewed in this way it is a domestic transaction, but with the purchaser holding title to future payments instead of consuming the goods. The process is reversed when, as, and if loans can be paid for by an excess of imports. In that case the domestic purchasers and consumers of foreign goods reimburse the holders of foreign bonds, which are thus retired. To the extent that this normal procedure is followed, the transaction still remains a domestic one.

But this normal method of repayment is almost impossible for us, both politically and practically. The repayment and servicing of large-scale foreign loans requires changes in the balance between our domestic and foreign sources of supply which we are unwilling, and may be unable, to make. The net result of the difficulty in repayment is therefore a domestic shift in wealth distribution from the American lender to the American producer of export goods, and since these goods were consumed abroad, they are subtracted from the possible total of domestic consumption.

From the above considerations it is evident that foreign indebtedness is an important contributory cause of instability, and a primary cause of some degree of lowering in the scale of living. It also appears as an agent in the redistribution of wealth as between the investing and the manufacturing classes.

The financial causes and factors are of primary importance. While the business and profits, and the savings and investment factors, set the stage, credit inflation furnishes the energy for destructive speculation, and unwise banking weakens the structure and broadens the collapse.

AGRICULTURAL CAUSES

(33) *The post-war deflation* [see (30) and (31)] bears with special severity *on agriculture*, particularly that devoted to the staple cereals.

During the war the collapse of European production stimulated our own. The prices of farm products were artificially set to prevent excessive profiteering. At the same time official encouragement was given particularly to the production of foodstuffs. As a consequence younger and more enterprising farmers took over larger and larger acreages from the older owners, usually on mortgages at the prevailing inflated prices. This policy was spectacularly effective in its immediate results, but has left the farmers with an undue proportion of that burden of debt already described. As investors in farm mortgages, banks and insurance companies are sharing in the burden.

The results of war inflation in agriculture are a primary cause of instability, of a lowering of the scale of living, and thus of an inequality in distribution as between agricultural and other classes who are less directly affected.

(34) *New producing territories and new productive methods* have played a part in agricultural distress, although the per capita production of farm products in the United States has been decreasing since 1915.

Wheat is not only feeling the impact of the expansion of new territories, in Canada and Russia, but also that of new varieties and processes. The new processes, largely mechanical, result in a great increase in both acreage and production per acre. They also make possible a satisfactory extension of the industry into more arid regions than had before been thought usable.

The same extension of areas applies to cotton. In foreign countries there are Egypt, the Sudan, and Turkestan; in the United States the climatic and other conditions of the new cotton fields of northwestern Texas have led to improved and more economical methods of production. This increase in output has met a decrease in demand due to the introduction of rayon and the vagaries of fashion.

These circumstances and conditions are among the causes responsible for present economic conditions in this country.

(35) *Crop surpluses* have been another disturbing factor. For the years 1927 to 1930 the annual production, in general, of the great staple crops has been

high, although not the largest crops on record. In wheat, however, the average world production for these four years was over 4600 million bushels per year, as compared with an average of less than 4000 million bushels annually for the preceding six years. The production of the U.S.S.R. is included in these figures. The principal causes of the surpluses in the United States were the reduction of consumption and loss of exports.

(36) *Agriculture as a business* has certain difficulties of its own. It is burdened with too high land values, it has been injured by loss of exports, it has suffered since 1929 from low prices for its products, and it must operate under a wide range of production costs, the spread being between those of the most efficient and least efficient production. In the case of foodstuffs it meets a comparatively inelastic market. Production cannot be accurately gaged in advance, due to the uncertainties of weather and crop-influencing conditions. Agricultural output is under control through only one factor, and but once a year, at planting time, which is many months before harvest. During the growing period conditions may and do arise which indicate acreages quite different from those planted, provided they could have been foreseen. Staple agriculture is essentially unstable.

Agricultural methods of operation are so complicated and under the best of conditions so completely mechanized that farming cannot absorb the unemployed released from industrial occupations, except on the basis of subsistence farming, a standard of living which would tend to destroy everything desirable in our social structure. To be a source of national strength, agriculture must be treated as a manufacturing industry.

By its very size agriculture is a preponderating factor in the market for goods, and, for that reason, its well-being is vital to national prosperity. However, it is inherently unstable, and further, because of its peculiar exposure to the evils resulting from war financing and war production policies, it is in a situation of distress which is a primary cause of the lowering of the attainable standard of living, and in the uneven distribution of wealth.

GOVERNMENTAL CAUSES

(37) *Tariffs* interfere with the free flow of goods from country to country, and are thus an element in preventing the attainment of a natural, world-wide equilibrium. It is commonly assumed that such an equilibrium is desirable. But equilibrium assumes a tendency toward the leveling of the scale of living in proportion as special advantages of different areas tend to diminish, as is the case at the present time. At this particular stage of industrial development and of the diffusion of techniques and mechanisms, the first result of ideal free-trade conditions would appear to be the emergence of the scale of living to the position of being the decisive element in world competition. In such a situation our own scale of living would be inevitably depressed below what is physically attainable.

World forces in actual effect at the moment tend to put a new aspect on the tariff question. It is appearing as a tool of conscious social control, rather than as a support for special interests. In proportion as this change can be recognized and assisted, this factor may be made a primary element of stability, and contribute to a raised scale of living.

(38) *Restraint of business* by government interferes with free adjustments internally as do tariffs externally. Among the governmental interferences may be mentioned the anti-trust laws, railroad rate, and other forms of control by the Interstate Commerce Commission, and the attempts to control prices of commodities artificially, as wheat and cotton prices by the Farm Board.

Of these examples the control of railroad rates has been undoubtedly the most complete and effective. It is also illustrative of the difficulties of arbitrary economic management in a complex industrial society. The rate structure is of such complication and of such delicate balance that no changes can be made except after much study and with great care. It is doubtful if as satisfactory a structure could have been built up by conscious design as was originally developed by free competition. The evils of that competition were obvious, but its services are no less so.

As to the control of prices, when the government seeks to fix the price of any commodity, that very attempt prevents the setting of proper prices, except under conditions of national emergency, such as war.

Other forms of governmental authority have pointed to similar complexities in the exercise of arbitrary control, and give support to the view that such policies, even when unavoidable, are at least contributory causes of unbalance. This cause was discussed from another angle under (15).

(39) *The burden of taxation* is annoying in prosperity, but scarcely endurable in times of depression. In part it is a reflex of the tendency to spend a growing proportion of our income in various forms of social expenditure, instead of in personal consumption. To the extent that this choice is consciously made, and the expenditures are economically administered, the increased taxation is not only inevitable but desirable.

In part the present burden of taxation is derived from war financing and war obligations. To the extent that these were necessary and inescapable the burden is justified. A considerable portion of them was unnecessary and at present escapable, and this portion is classed by many as an unjustifiable burden.

Finally, the burden of taxation has been multiplied by the deflation since the war, as represented by the expenses of servicing and retiring the national indebtedness in dearer money than that originally borrowed. In this aspect the burden of taxation is one of the incidences of the burden of debt.

Under the present fiscal ideals which endeavor to equalize the volume of taxation over good times and bad (though with little success), taxation during the depression is a handicap to recovery so far as the psy-

chology of recovery requires the attainment of profit conditions.

The burden of taxation would appear to be a contributory cause of business unbalance and a factor in the distribution of wealth. It affects the average scale of living in the sense that it may divert purchasing power from personal to social consumption which may or may not be preferred.

(40) *Public construction* in its total volume of municipal, county, state, and federal undertakings, is of a magnitude which can only be roughly estimated. It is clear that the volume is sufficient to make it an important element in the total volume of business. To the extent that the fluctuations of public construction coincide with those of private business, it would appear to add to those fluctuations. To the extent that the two classes are out of phase they will tend to diminish the amplitude of the total variations. This is merely the obvious, primary effect. There are doubtless important secondary effects not clearly recognized.

The present coincidence of the variations in public and private activity accentuates as well the fluctuations in employment, and concentrates public expenditures in the period when costs are highest.

It is evident that any method of improving this situation will have to take into account the favorable period for taxation, and provide some as yet unapplied means for carrying over funds from prosperous to depression periods, when they can be employed most effectively and economically. This problem lies rather in the category of remedies than of causes, and is not discussed further.

The various governmental acts bring serious forces to bear on the economic problem, but in so diverse a way that it is not possible to evaluate them.

SUMMARY

By way of summary, the Committee restates the fact that the causes of business instability naturally fall into the seven groups presented in this report, and on the whole, the items in each group are so related as to lead to the surmise that the effective remedies may be more or less in common, that is, the rational structure presented by the causes suggests a corresponding structure of appropriate remedies. Part II of this report is given over to an analysis of a selected group of suggested remedial plans and programs.[11]

R. E. FLANDERS, *Chairman*
L. P. ALFORD
F. J. CHESTERMAN
DEXTER S. KIMBALL
F. H. MCDONALD
L. W. WALLACE
W. J. WILGUS.[12]

[11] Part II will appear in the May issue.

[12] In signing this report Mr. Wilgus desires to express his belief that in it sufficient stress has not been given to betrayals of trust and other violations of common honesty as primary factors in the upsetting of economic stability. He considers that this is a real underlying cause not to be lightly dismissed as of secondary effect.

Nesmith

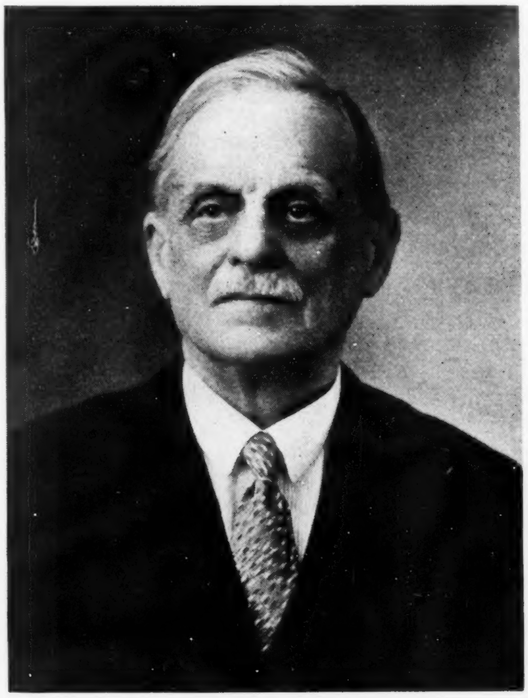
ELIHU THOMSON:

Some of His Mechanical Inventions

Two years ago this veteran inventor, engineer, and scientist was made an Honorary Member of the A.S.M.E. In celebration of his eightieth birthday, Dr. Compton interestingly recounts here a number of Professor Thomson's achievements in a field closely allied to the electrical one to which he has brought such honor and renown.

By KARL T. COMPTON[1]

ON THE twenty-ninth of March, Elihu Thomson, Director of the Thomson Research Laboratory of the General Electric Company, celebrated his eightieth birthday. At an age when most men have long since retired from professional responsibilities, this distinguished leader is still active and creative and intensely interested in the direction of the important research work going on in the laboratory which bears his name. Looking at Professor Thomson's life in retrospect, there is only one conclusion to be drawn: His has been a rich and fruitful life in every way, and one of outstanding contribution to science, engineering, and society at large.



ELIHU THOMSON

At the age of eleven, being too young to enter high school, Elihu Thomson obtained several boys' books on scientific and mechanical subjects, and, inspired by these, proceeded to construct for his own amusement a variety of the electrical devices which were the absorbing scientific interest of that day, such as batteries, Leyden jars, electromagnets, and telegraphic instruments. He constructed a frictional static machine out of an old wine bottle, and when his father did not seem sufficiently impressed by the tiny sparks it produced, he went to work and constructed a large static battery which he demonstrated so effectively that the elder Thomson was all but disabled.

This interest and genius, already evident at the age of eleven, has been equally and continuously present throughout the long and wonderfully active career of Professor Thomson. He is the holder of more than 700 U. S. patents, which is the second largest number held by any living man. He is honored and respected by every scientific, engineering, and educational institution in the world (from 1921–1924 he was Acting President of the Massachusetts Institute of Technology, and at present is on its Corporation and a non-resident member of its Faculty), and in Lynn, Massachusetts, he is more responsible than any other man for the great electrical industry which supports thousands of people there. For good reasons he has been aptly called "the dean of electrical engineers."

Although his talents have been effectively employed in many lines, it is in the field of electricity that his genius has found its greatest scope and has led to the most important achievements and wide-spread service. Nevertheless his contributions in the mechanical field have been by no means unimportant, and, indeed, no small number of his patents come in this category. It is just this work of his along mechanical-engineering lines which will be the object of the brief survey that follows. Even in this field, however, his inventions have been so many and varied that it is impossible to do justice to them all. Only a selected few, therefore, will be mentioned.

Jointly with his first colleague, Professor Houston, Professor Thomson invented and patented the continuous centrifugal cream separator in the years 1877 to 1881. This was a device applicable to the separation of substances of different densities, and has come into universal use in creameries as well as in the laboratory and else-

[1] President, Massachusetts Institute of Technology, Cambridge, Mass.

where for centrifuging mixtures which it is desired to separate. A typical claim in the patent is this: "A process of creaming milk mechanically, skimming off the cream mechanically, and removing the skimmed milk mechanically by centrifugal force." The principles employed have become fundamental in all centrifugal separators. At the time of his invention Professor Thomson could not have dreamed that this same process of separating materials by centrifugal force would later be used by a brilliant young physical chemist of the Massachusetts Institute of Technology for separating the molecular ions of electrolytes and obtaining their relative weights.

AIR-BLAST MECHANISM FOR COMMUTATOR-SPARK PREVENTION

Many of his mechanical inventions were naturally in connection with appurtenances for his electrical devices and for the purpose of improving their usefulness and reliability of operation. The Thomson air-blast mechanism of 1882 is in this class. One of the difficulties encountered in the early Thomson-Houston arc dynamos was the sparking at the commutators, resulting in complete flashovers when the load was increased too much. With the air-blast mechanism Professor Thomson obtained control of the commutation to such an extent that with a single three-segment commutator the large Thomson-Houston arc dynamos could be operated with perfect success under loads of from 75 to 80 arc lights in series, whereas without the air blast the limit was about 12 arcs in series for a single-commutator generating system. This air-blast mechanism was used on practically all the Thomson-Houston dynamos manufactured.

The valuable feature of the invention is the introduction of a powerful jet of non-ionized air at the exact time when the zeros of the current alternations occur, thereby preventing the actual establishment of the incipient alternating-current arc. In his patents the use of other insulating fluids, such as oil, is also described. Here Professor Thomson evidently hit upon a fundamental idea for current interruption. It is well known how in recent years this principle has been applied extensively in the various designs of large circuit breakers for the control of vast power networks. Indeed, these applications may be said to have been foreshadowed in his invention of the air blast.

OIL-BURNING FLASH BOILER

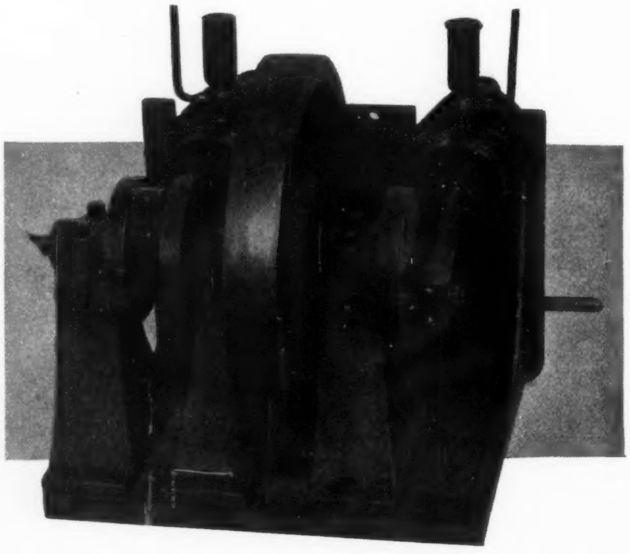
Another development in which Professor Thomson has been deeply interested is that of steam generation and its subsequent utilization in high-efficiency engines. In 1901 he obtained a patent for a "vapor generator" which was virtually a steam boiler and an oil burner combined into a very moderate-sized structure in relation to the output. In this the fuel (oil or kerosene) is pumped through a small passage, while the exact amount of air for complete combustion enters through another passage in the head which acts as a sprayer. The pumping apparatus furnishes air and oil in exact proportions for complete combustion, and the supply may be increased or diminished at will.

The experimental apparatus was about six inches in overall diameter, and the furnace part less than half of this. The water passed through and was evaporated in a spiral tube of flat cross-section. This boiler would burn five pounds of kerosene oil per hour perfectly without smoke or odor, and produce highly superheated steam at a pressure of 170 to 180 pounds per square inch, using cold water fed at a rate of 70 pounds per hour. This performance represented 14 pounds of steam per pound of oil as compared with an estimated maximum of 16 pounds, and hence gave the device as a boiler an efficiency of 80 per cent. Furthermore, no hot flue gases were evolved. In fact, the exhaust was so cool that the hand could be held in it steadily without more than a moderate warmth being felt.

In developing this boiler, Professor Thomson had its application to automobiles in mind, but evidently it might be equally useful for many other purposes. One important feature in this connection is its ability to relight three hours after extinguishment simply by turning on the fuel supply. It seems, however, that his pioneer work in this particular field has never received the attention which it actually deserved.

PROFESSOR THOMSON'S "UNIFLOW" ENGINE

Hand in hand with his work on the above-mentioned boiler was his development of a high-efficiency engine. In his patent of 1903 this is termed the "fluid-pressure" engine. Again he had the application to automobiles in mind. It was a non-condensing reciprocating engine involving a somewhat novel principle in that the steam was permitted to flow in one direction only—from the intake to the exhaust—never turning



ORIGINAL TWO-CYLINDER STEAM ENGINE OF HIGH EFFICIENCY, EMPLOYING PRINCIPLE APPEARING LATER AS UNIFLOW TYPE

back to come once more in contact with the heated surfaces. He described its principle in the following words: "The conditions are such that there is no retraversing of passages, no retraversing of even the cylinder portion. The steam enters, goes forward and out, keeps running steadily forward, so that we do not have any of those interactions that use up energy. We have a temperature gradient from one end to the other of the steam cylinder."

The test on the first engine built by Professor Thomson indicated great economy. Thus a four-cylinder engine of this type gave 5 horsepower on an expenditure of 17.25 pounds of water per horsepower-hour, which was a remarkable result at that time.

No doubt Professor Thomson here laid down a new and important principle for engine design. Engines built on this principle are now generally known as "uniflow" engines, and have been manufactured and used to a considerable extent, especially in Germany.

In 1903 Professor Thomson devised a "regulator for vapor generators." The patent therefor covers a system which found application in steam automobiles using kerosene oil as fuel. It provides for effective regulation of the fuel supply to the burner, and also for regulation of the steam temperature and pressure by control of the water feed to the boiler. This device has been used in a number of automobiles built at Lynn.

FLASH BOILER FOR STEAM (UNIFLOW) ENGINES RUN BY EXACT MEASURED SUPPLY OF WATER, OIL (KEROSENE), AND AIR

GAS- AND OIL-ENGINE INVENTIONS

Another interesting invention is that of a gas or oil internal-combustion engine (1902), which, however, has never been put into commercial use. The model first built had two cylinders, one larger than the other. The smaller cylinder took in the fuel charge, while the larger one took in air only. When the fuel charge was fired (as by hot-tube ignition) the whole charge, burning with fuel in excess, was transferred into the volume of compressed air contained in the larger cylinder. Hence it was called the "transfer-type" engine. It gave good results as far as economy was concerned, and a special and important feature was the clean exhaust, containing no carbon monoxide or smoke, due to complete combustion of the fuel in an excess of air. In such respects it represented a pioneer invention. While this engine was of the four-cycle type, a subsequent development resulted in a similar two-cycle engine operating on the same principle.

In 1904 Professor Thomson devised a muffler for gas engines (applicable to automobiles, for instance) which was based upon the sound scientific principle of dividing up an impulse or sound wave so that it would traverse a number of paths of unequal length. When these divided impulses all came together again they would be out of phase and partially neutralize each other, thus tending to dissipate the shock of the initial impulse.

Another invention of a somewhat different nature, and which possibly may have been the result of Professor Thomson's fondness for music and his interest in organs and other musical instruments, is that of a music-sheet guiding device. The patent covering this device, issued in 1907, relates to the guiding of a perforated music record over a "tracker" with holes corresponding to the different notes in such a way that the holes in the record register laterally with the tracker holes. Concerning this invention, Professor Thomson says: "I applied this device to my house organ installed in 1903, and it is still in use in 1930. It has not been changed and works well. It is in fact of fundamental character in this field, using the edge of the music-record sheet to adjust the record to its proper position. The mechanism is naturally pneumatic and keeps the paper sheet in place so closely that the variation to right or left during playing is only about one-hundredth of an inch or less. Without this attachment the whole instrument would be far less effective for automatic playing. Thousands of these devices have been used commercially."

An interesting speed indicator was invented in 1914. This instrument really gave such good results that it ought to have been manufactured and sold on a large scale. It depends on the revolution of a fluid (mercury) and the drag of this fluid on a movable vane on the indicator shaft, which vane is returned to zero by a coiled spring when the mercury is not in motion. A number of these instruments have been made and used in the General Electric factories at Lynn.

A hydraulic clutch mechanism was also invented and patented in 1914. The arrangement combines in one device a centrifugal pressure pump, a piston operated by the pressure, and a multiple-disk clutch operated by the piston, and is intended for use in automobiles, etc. The control is by means of a bypass valve worked by the operator.

HIS WORK ON FUSED QUARTZ AND HUGE TELESCOPE MIRRORS

In quite a different line of activity Professor Thomson's

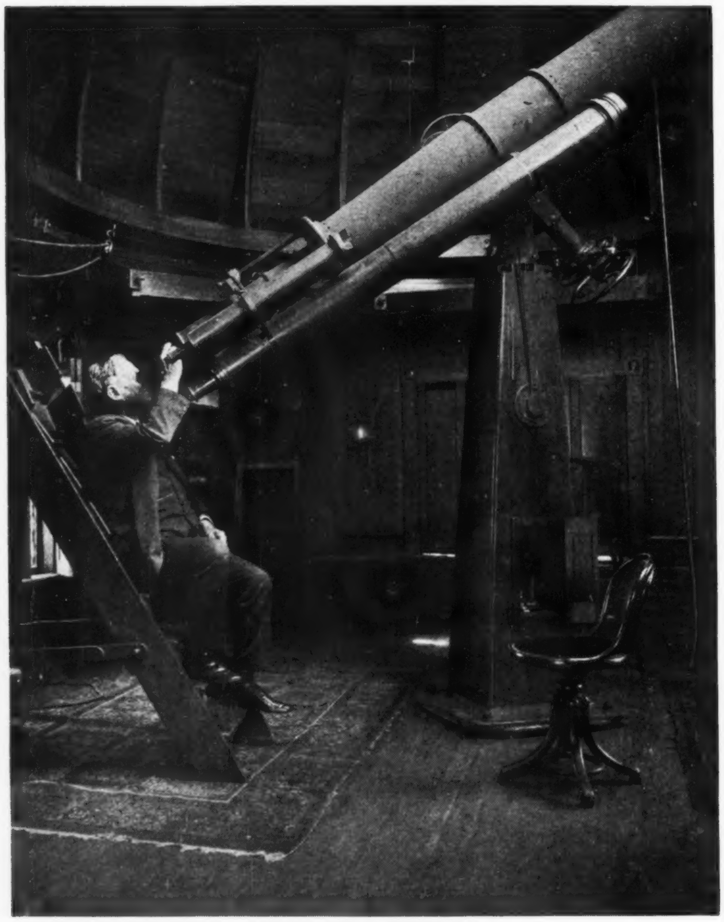
interest has continued unabated from the time quite early in his career—in 1878—when he published an account of a new method of grinding and polishing glass mirrors such as are used in telescopes. His interest in optical instruments led to an intense study of and experimentation with fused quartz. Many patents have been taken out by him since 1902, covering the numerous aspects of the processes involved in its manufacture and handling. The methods perfected under his direction have proved markedly successful and permit the construction of quartz apparatus in size and quality hitherto unapproached. The quartz is fused in especially designed furnaces, is forced under pressure into forms or molds, and solidifies under pressure, the small air bubbles always present in earlier quartz ware being compressed to such minute dimensions as to be entirely invisible. The method represents a tremendous advance over the old-fashioned one of building up quartz apparatus by the individual work of a glass blower fusing on dab after dab under a blowpipe flame. This new type of quartz ware, eminently applicable to optical instruments in the form of mirrors and lenses, is also coming to be extensively used as a transmission glass for ultra-violet light in hospitals and in special lamps. It has also been used in making windows for diving bells, where its almost perfect transparency, with its ability to withstand enormous pressures, has made possible deep-sea investigations at much greater depths than even heretofore.

Quite recently, Professor Thomson has had entrusted to his inventive skill the problem of investigating the feasibility of constructing very large telescope mirrors of quartz. In this work he has met with complete success and has definitely demonstrated the possibility of using quartz for the manufacture of such mirrors.

HIS RARE COMBINATION OF QUALITIES

More than any man now living, or in fact, more than any man in history, Professor Thomson has combined in a most remarkable way the constructive powers of the inventor, the thoroughness and soundness of the man of science, and the kindly balance of the ideal philosopher, teacher, and friend. Because of these qualities he is held in equally high esteem by practical engineers and by those in the most exalted academic circles. He has always shunned publicity, and because of this his achievements have not been highly advertised or blazoned on the front pages of the newspapers; but I think all will agree that a fair appraisal of the importance of his work to the industrial and intellectual interests of the entire world demonstrates that this man deserves in every way the tribute which was paid him by my predecessor and his friend, Dr. Richard C. MacLaurin, President of Technology from 1909 to 1920, who said: "In his laboratory, built right into his house and an integral part of it, he is a man from whose mind probably thoughts on scientific problems are never wholly absent, an unselfish genius, a well-trained, well-rounded, well-balanced man of science;" or in the words of the *Electrical World* on the occasion of the awarding to Professor Thomson of the Faraday medal of Great Britain in 1927: "And how proud the electrical industry is of her Swampscott inventor, philosopher, and friend. Of all men living, none except Edison has brought her so much honor and renown."

We may well, on the occasion of his eightieth birthday, extend to him our respectful greetings and thanks, and add a sincere wish that he may be given to enjoy many more years of good health and useful activity.



PROFESSOR THOMSON IN HIS OBSERVATORY IN SWAMPSCOTT

DUST *in* INDUSTRY

The Sampling and Analysis of Industrial Dusts

By J. J. BLOOMFIELD[1]

THE abundant evidence at hand showing that the inhalation of certain industrial dusts is an important factor in the causation of pulmonary disease has emphasized the significance of the quantitative aspects of this problem. A knowledge of the dust content of the industrial atmosphere is required not only for the purpose of determining the extent of the hazard involved in various manufacturing processes, but is also useful in measuring the efficiency of protective devices which may be used in the elimination of the dust hazard. The object of the present contribution is to describe the underlying factors involved and the technique employed in the study of the quantitative phases of the industrial dusts which may produce injury to the respiratory system. Such dusts are produced by the numerous industrial operations involving the drilling, crushing, and grinding of mineral matter such as talc, quartz, granite, slate, and cement.

The properties of a given dust which determine its capacity to produce pulmonary pathology are the nature of the dust, that is, its chemical and mineralogical composition, its particle size, and finally the quantity of the dust dispersed in the atmosphere.

One of the outstanding results of the last 20 years of research in the field of dust inhalation is the demonstration of the fact that, in general, the degree of health hazard associated with the inhalation of any dust, all other factors remaining constant, is dependent upon the mineralogical composition of the dust. For example, it is now well established that the inhalation of certain types of dust, such as granite dust, will in time produce fibrosis of the lungs, frequently associated with tuberculosis. In other cases exposure to dust may result in the production of a far lesser degree of fibrosis without subsequent tuberculosis; this is true of cement dust. And finally, there are certain types of dusts which produce little or no lung fibrosis, as typified by marble dust. In general, it has been found that those dusts which are high in quartz content are the ones which produce a disabling fibrosis of the lungs most readily. Hence the necessity for knowledge concerning the chemical and mineralogical composition of a dust is obvious.

So far as the size of the dust particles is concerned, it is apparent that in order for any given dust to produce injury to the lung it must gain access to the parenchyma of the lung, the site where the harmful effects of the dust take place. It is known that not all of the particles of inhaled dust gain access or are retained by the human lung. For this reason it is essential to determine the size of the dust particles present in the industrial atmosphere.

With reference to the quantity of dust present in the air of a workroom, it is apparent that when the dust concentration is high the exposed person will inhale a greater quantity in a given period of time than he will when it is relatively low, and since the rate of production of the disease is partially dependent upon the total amount of dust inhaled, this latter fact plays an important rôle in determining the time of onset of the end result. The need for the evaluation of the quantity of dust in the industrial atmosphere is obvious.

NATURE OF DUST

Research on the problem of industrial-dust inhalation has demonstrated that so far as their fibrosis-producing qualities are concerned, dusts may be divided into three groups: (1) those composed completely of combined silica, that is, silicates, such as pure asbestos; (2) those containing free silica in the crystalline form known as quartz (granite contains approximately 35 per cent of quartz), and lastly, (3) dusts containing free silica in a non-crystalline form such as diatomaceous earth. In general it has been found that the harmfulness of a quartz-containing dust is in direct proportion to its quartz content. For this reason in attempting to evaluate the harmfulness of a dust it is of the utmost importance to ascertain its quartz content. This should be done by a chemical and mineralogical analysis.

We find in practice that samples of dust settled out of the atmosphere at the breathing level of the worker serve admirably for these chemical and mineralogical determinations. It is our practice to have such analyses made by an expert geologist. Only in this way is it possible to determine accurately the amount of quartz present in a given sample. Table 1 presents the quartz

TABLE 1 PERCENTAGE OF QUARTZ PRESENT IN VARIOUS INDUSTRIAL DUSTS

Kind of dust	Percentage of quartz
Rock-drilling dust (bituminous-coal mine)	54.0
Granite-cutting dust	35.2
Rock-drilling dust (anthracite mine)	31.0
Brass-foundry dust	19.0
Dust from raw mills in cement plant	6.5
Slate-mill dust (Vermont red slate)	3.0
Silverware-polishing dust	1.7
Anthracite dust	1.5
Bituminous-coal dust	1.2
Cement dust	less than 1.0
Slate-mill dust (Vermont green slate)	trace
Talc-mill dust	none
Marble-cutting dust	none

[1] Sanitary Engineer, U. S. Public Health Service, Washington, D. C.

Presented at the National Process Meeting arranged by the Process Industries Committee of the A.S.M.E., and held under the auspices of the Buffalo Section of the Society, Buffalo, N. Y., June 6 to 8, 1932.

content of dusts obtained in various industries which we have studied.

It is quite evident that, judged by quartz content, rock-drilling occupations in the coal-mining industry and certain occupations in the granite-cutting industry and in brass foundries may be considered as hazardous. That this is true is evidenced by the high rates of illness and death from silicosis and tuberculosis in some of these industries.[2]

PARTICLE SIZE OF DUST

It has been demonstrated that particles of a size greater than 10 to 12 microns in the longest dimension are very seldom found in the lungs. This absence of larger particles is partly due to the fact that the number of such particles greater than 10 microns in size present in industrial air is, as compared with the lower sizes, comparatively small, and, due to gravity and the protective action of the mucous surfaces of the upper respiratory tract, these larger particles do not penetrate to the terminal portions of the respiratory tract. Hence we need only concern ourselves with those dust particles that are less than 10 microns in the longest dimension.

In order to ascertain whether or not an industrial dust is capable of gaining access to the lungs, it is necessary

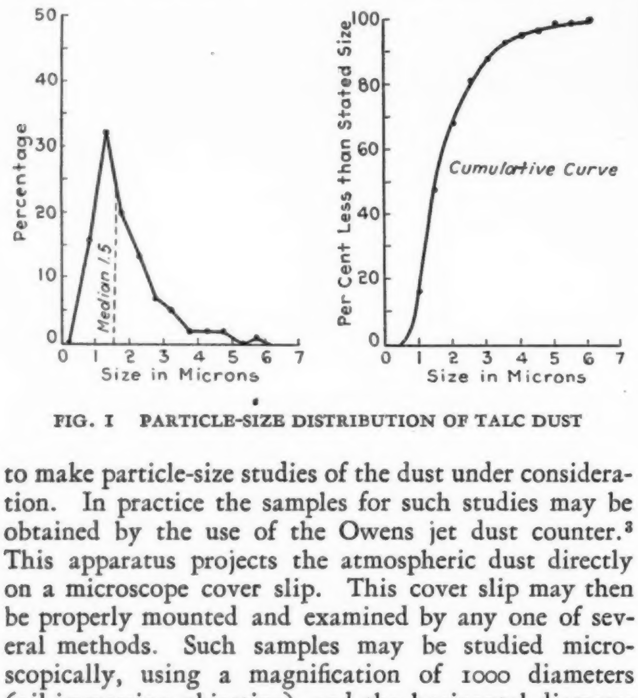


FIG. 1 PARTICLE-SIZE DISTRIBUTION OF TALC DUST

to make particle-size studies of the dust under consideration. In practice the samples for such studies may be obtained by the use of the Owens jet dust counter.[3] This apparatus projects the atmospheric dust directly on a microscope cover slip. This cover slip may then be properly mounted and examined by any one of several methods. Such samples may be studied microscopically, using a magnification of 1000 diameters (oil-immersion objective), and the horizontal diameter of a representative number of particles measured by means of a calibrated filar ocular micrometer.[4] In another method a photomicrograph of the dust is made at a high magnification (1500 to 2500 diameters); from this either an enlarged print may be made, or the negative may be enlarged by means of a stereopticon. The particles revealed on the enlarged print or screen may be measured by means of a millimeter scale. The particle-size dimensions are grouped in classes according to size, from which a percentage distribution curve is easily obtained. Fig. 1 presents the particle-size distribution of talc dust from the air of a workroom in which talc

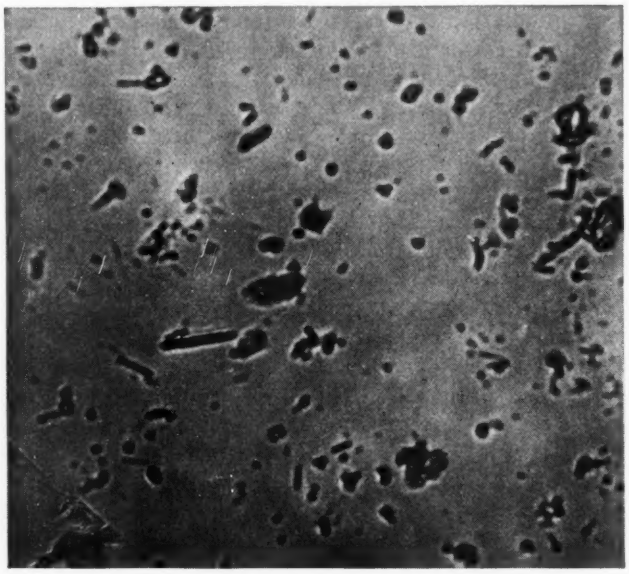


FIG. 2 PHOTOMICROGRAPH OF TALC DUST OBTAINED WITH THE OWENS JET DUST COUNTER. X650

was being ground to a very fine state of subdivision. The measurements, from which the data for this figure were obtained, were made by means of a filar ocular micrometer at a magnification of 1000 diameters. With this magnification it is possible to measure particles as small as 0.5 micron in diameter, while particles smaller than 0.5 micron are easily distinguished at this magnification, and, although not measured, their presence is recorded. For routine particle-size measurements the photomicrographic method as described by Green[5] has a decided advantage over the direct microscopic measurements, in that the task is less tedious and the particles are measured with more ease and accuracy. However, for all practical purposes the filar-micrometer method should fulfil the required needs.

An examination of Fig. 1 shows that only 16 per cent of the particles were found to be less than 1 micron, the major portion (65 per cent) being between 1 and 2.5 microns in size. The median size of the dust was found to be 1.5 microns. Fig. 2 is a photomicrograph of the same specimen of dust.

QUANTITY OF DUST

As pointed out earlier, a knowledge of the quantity of

[2] Russell, A. E., Britten, R. H., Thompson, L. R., and Bloomfield, J. J., "The Health of Workers in Dusty Trades. II. Exposure to Siliceous Dust (Granite Industry)." Public Health Bulletin No. 187, July, 1929.

[3] Owens, J. S., "Jet Dust Counting Apparatus," *Jl. Ind. Hygiene*, April, 1923, p. 522.

[4] Hatch, Theodore, and Choate, Sarah P., "Statistical Description of the Particle Size Properties of Non-Uniform Particulate Substances," *Jl. Franklin Inst.*, March, 1929.

[5] Green, Henry, "A Photomicrographic Method for the Determination of Particle Size of Paint and Rubber Pigments," *Jl. Franklin Inst.*, vol. 192, no. 5, p. 637, Nov., 1921.

dust dispersed in the industrial atmosphere is very important, since with any given dust the rate of production of the injury will be dependent upon the total quantity of dust inhaled.

The author feels that from the hygienic viewpoint the particle count is at present the best index of the degree of atmospheric pollution. The decision as to the size range of the particles which should be included in the dust count is a question requiring careful consideration. Obviously the size of the smallest visible particle will depend on the magnification and type of illumination used in the microscope, the refractive properties of the dust, and, to some extent, on the visual acuity of the observer. We must bear in mind that our chief interest in this problem is in its industrial and hygienic aspects. Primarily we are interested in differentiating between the dust content in ordinary normal atmospheres, not known to be harmful, and certain industrial dusts which are known to be associated with lung damage. This difference is sharply marked as far as the dust particles between approximately $^1/_2$ and 10 microns in diameter are concerned; but the difference between such normal and abnormal air is masked and lost when we include in our determination the particles of ultramicroscopic size which are present in vast numbers in all air.

So far as the upper limit of particle size is concerned, it has been demonstrated by the South African studies that particles greater than 10 microns in the longest dimension are of negligible importance. The data concerning the lower size limit of potentially hazardous dust is not so conclusive. The only available data which throw some light on this point are found in the work of Moir,[6] of South Africa, who examined microscopically 120 dust particles obtained from two specimens of silicotic lung and found that only 13 per cent of the particles were less than 0.5 micron and about 36 per cent of the particles less than 1 micron in diameter. The majority of the particles (60 per cent) were between 1 and 3 microns in size. The median size of the dust was found to be 1.2 microns in diameter. Practically the same results were obtained by Watkins-Pitchford,[7] who examined and measured the silica particles in sections of silicotic lungs illuminated by polarized light. Drinker,[8] in comparing the size frequency of the particles measured by Moir with the particles found by him in the sputum of men employed in ore mills, found a close correspondence. The findings of Moir and Watkins-Pitchford have also been corroborated by Mavrogordato,[9] who examined dust both with light and dark ground illumination, in sections of human and animal silicotic lungs as well as the dust recovered from these lungs. As a result of his work and that of his colleagues in South Africa, Mavrogordato says: "In the damaged lungs, as far as simple silicosis is concerned, the lesions are discreet, localized, and associated with visible particles; whereas, if the ultramicroscopical particles were an important agent, one would expect the simple disease to be generalized and to show no particular association between lesions and visible particles."

In connection with the lower limit of particle size of dust of pathologic significance, the following pertinent question arises: Aside from the evidence direct or indirect of the non-retention of minute particles of dust by the lungs, what evidence is there that appreciable percentages of ordinary industrial dusts ever fragment into those minute sizes less than 0.5 micron in diameter? It is a well-known fact that in most of the fine-grinding operations in use today, such as in the preparation of paint pigments, considerable energy must be expended to obtain a product the particle size of which is less than 0.5 micron in average diameter, and this not in an industry where dust is an evil by-product but where finely divided dust is the chief aim of the whole industrial process.

The best answer to the question just raised, namely, What is the particle-size distribution of industrial dust? would be data of actual measurements of such dust. Unfortunately we have but scant published data to date on the particle-size frequency of dusts in the air of industrial establishments. In 1929, Fehnel[10] reported some particle-size dust measurements in connection with a dust study of hard-rock drillers in New York City. As a result of his study, Fehnel reported the findings on three samples, which showed the dust, which was less than one micron in size, to vary from 1 to 15 per cent. Most of the dust in these hard-rock drilling operations was, according to Fehnel, between 2 and 5 microns in size.

Badham,[11] in studying the dust hazard among sandstone workers in Sydney, measured some 16,000 particles of dust in the air of work places and found that 67 per cent of these particles were about 1.5 microns in size. From his study Badham states: "It would appear that below 10 microns there is no selective action by the dust cells of the lung, and that the particles found in the lung have the same size-frequency as those in the air breathed...."

In a particle-size study of 10 samples of aerial industrial dusts made by the filar-micrometer method at a magnification of 1000 diameters, the author found that practically all of the dust was less than 5 microns in size. Only 1 per cent of the particles was less than 0.5 micron, 18 per cent were less than 1 micron, and the majority of the dust (73 per cent) was found to be between 1 and 3 microns in diameter.

From all of the evidence just presented and in the ab-

[6] Moir, J., "Report on a Specimen of Dust From Silicotic Lungs," General Report of the Miners' Phthisis Prevention Committee, Pretoria, 1916, Appendix 9, pp. 138–140.

[7] Watkins-Pitchford, W., "The Situation, Outline and Dimensions of Mineral Particles Visible by Polarized Light in Sections of Silicotic Lungs, Mounted in Canada Balsam." General Report of the Miners' Phthisis Prevention Committee, Pretoria, 1916, Appendix 8, pp. 135–138.

[8] Drinker, Philip, "The Size-Frequency and Identification of Certain Phagocytosed Dusts," *Jl. Ind. Hygiene*, vol. 7, no. 7, July, 1925.

[9] Mavrogordato, A., "The Value of the Konimeter," Publication of the South African Institute of Medical Research, no. 17.

[10] Fehnel, William J., "A Study of Silica Dust in Hard Rock Drilling in New York City," *Jl. Ind. Hygiene*, vol. 11, no. 2, Feb., 1929.

[11] Badham, Charles, Reyner, H. E. G., and Broose, H. D., "Dust Sampling in Sydney Sandstone Industries," Report of the Director-General of Public Health, New South Wales, Dec., 1927, p. 74.

sence of conclusive proof to the contrary, it is apparent that we need only be concerned with those dust particles between $^1/_2$ and 5 microns in size, and from a practical standpoint the lower limit of particle size may well be taken at about one micron. The method of dust counting which we have used, the description of which follows, is capable of revealing particles as small as one micron quite readily, and in the hands of a trained person smaller particles may be enumerated.

Many methods have been devised and used for the

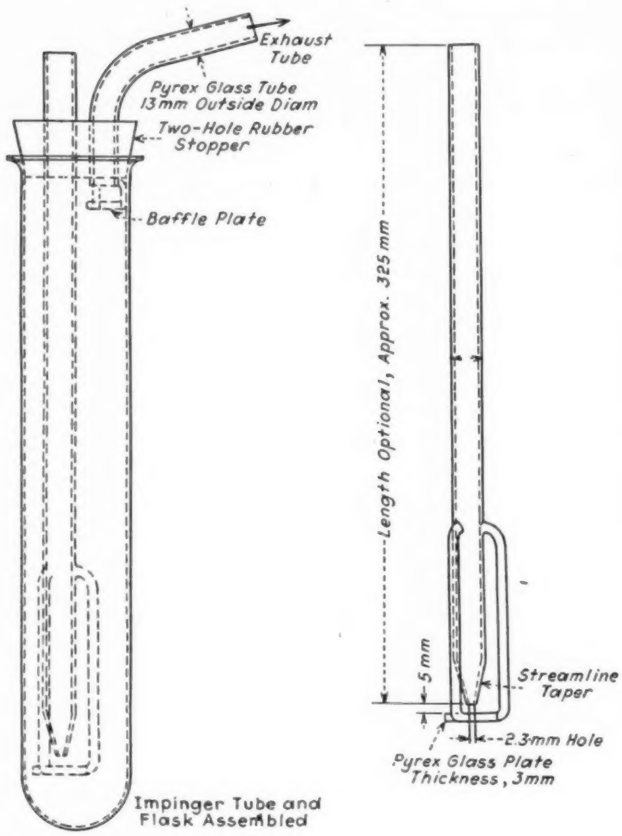


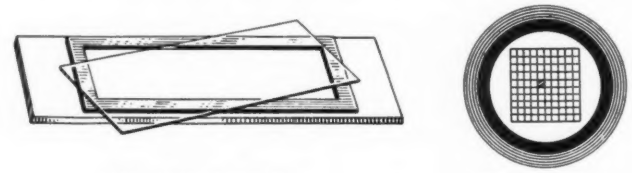
FIG. 3 ESSENTIAL PORTIONS OF THE GREENBURG-SMITH IMPINGER APPARATUS FOR DUST SAMPLING

purpose of determining the quantity of dust in air. These methods have already been fully discussed in an excellent review of this subject by Dr. Greenburg.[12] Suffice it to say that for the purpose of dust sampling in either high or low dust concentrations, the Greenburg-Smith impinger apparatus now finds universal favor.[13] This instrument has been used by the United States Public Health Service in all of its dust studies during the past nine years. It is also being used by other workers in this field both here and abroad.

In this instrument, the air to be sampled is drawn through a glass tube and impinged at a high velocity on a glass plate which is kept beneath the surface of the water or other suitable fluid in the collecting flask. The dust is momentarily arrested, wetted by the collecting fluid, and in this manner trapped.

The impinger apparatus consists essentially of two portions: first, a source of sufficient suction to draw the air to be sampled through the sampling device; and second, the sampling device or impinger itself, which consists of a container and the impinger tube and plate. As a source of suction one may use either an electrically driven pump or a compressed-air ejector device. Fig. 3 depicts the essential portions of the apparatus, which consists of a straight piece of Pyrex glass tubing 13 mm in outside diameter and approximately 325 mm in length. The tube is drawn down in streamline form at its lower end to a tip with a 2.3-mm orifice. A circular glass impinging plate approximately 3 mm in thickness and 25 mm in diameter is attached to the lower end of the impinger tube at a distance of 5 mm from the orifice by means of three glass rods. The collecting medium (distilled water) in the sampling flask is of sufficient volume to keep the impinger plate immersed at a depth of approximately 3 cm. In sampling, the outlet or suction elbow of the sampling flask is connected with the source of suction by means of a suitable length (25 ft) of non-collapsible rubber tubing. The duration of the sampling period should be such as to yield a satisfactory suspension of dust for analysis, and is thus dependent on the concentration of dust in the atmosphere. Under the usual industrial conditions, samples of from 10 to 30 cu ft of air yield sufficient suspended dust for analysis. Since a sampling rate of 1 cu ft per min is maintained, this will require a sampling period of from 10 to 30 min.

The collecting efficiency of the apparatus is dependent upon adherence to the previously cited impinger-tube dimensions and the sampling rate of 1 cu ft of air per min. Experimental tests of this instrument against suspensions of finely divided silica dust in air have con-



Sedgwick-Rafter Cell　　Whipple Disk

FIG. 4 SEDGWICK-RAFTER CELL AND WHIPPLE DISK EYE-PIECE FOR USE IN COUNTING DUST PARTICLES UNDER A MICROSCOPE

sistently yielded efficiencies of 98 per cent at the specified sampling rate.

Since practically all dusts are, to some extent, soluble in water, it is good practice to analyze the samples as soon as possible. Such practice tends to prevent any undue flocculation as well as any solvent action on the dust particles. In the laboratory[14] the dust suspension in the

[12] Greenburg, Leonard, "Studies on the Industrial Dust Problem," Public Health Reports, vol. 40, no. 16, April 17, 1925.

[13] Greenburg, Leonard, and Bloomfield, J. J., "The Impinger Dust Sampling Apparatus as Used by the United States Public Health Service," Public Health Reports, vol. 47, no. 12, March 18, 1932.

[14] For a more detailed description of the dust-counting technique, the reader is referred to a contribution in the Public Health Reports of March 18, 1932.

sampling fluid is filtered through a 325-mesh screen and then diluted so that the number of dust particles in the microscope field is equal to approximately 50 to 75. Two or more 1-cc portions are placed in Sedgwick-Rafter cells for counting (see Fig. 4). The microscope is of the ordinary type, provided with a suitable eyepiece and objective and fitted with an Abbé condenser. A Whipple disk-eyepiece micrometer (Fig. 4) is placed in the microscope eyepiece and the microscope tube length is adjusted so that the side of the ruling in the eyepiece is 1 mm in length. (We employ a 7.5 × eyepiece, 16-mm objective, and a tube length of 178 mm.) As a source of illumination we use an ordinary type of microscope lamp with the iris of the Abbé condenser system adjusted so as to provide a high degree of visibility. In making counts the microscope should be focused throughout the depth of the cell since some of the dust particles may remain in suspension. Since the counting cell is 1 mm deep and the area in the microscopic field is 1 sq mm, each count represents the amount of dust in a cubic millimeter of the sampling fluid. Knowing the original dilution of the sample and the number of cubic feet of air sampled, it is an easy matter to compute the number of dust particles in the sample per cubic foot of air. It is of course necessary to make control dust counts on the sampling fluid.

In Table 2 a summary is presented of the average dust content of the air in certain dusty industries. This table shows that the highest dust exposure was in the

TABLE 2 AVERAGE DUST COUNT IN CERTAIN DUSTY TRADES

Industry	Dust count in millions of particles per cubic foot of air
Slate-finishing mills:	
Floormen	1598.0
Loaders	1276.0
Disk-crusher operators	312.8
Talc mining:	
Jack-hammer drillers	2159.8
Muckers	44.8
Talc-finishing mills:	
Crushers and cylindermen	14.0
Packers	50.1
Marble cutters	32.8
Marble carvers	19.1
Granite quarrying:	
Leyner drillers	144.4
Jack-hammer drillers	112.1
Plug drillers	36.9
Cement mill, average of all operations	26.0
Granite cutting:	
Hand pneumatic-tool operatives	59.2
Machine pneumatic-tool operatives	35.9
Attendant labor	17.0
Anthracite mining:	
Miners and miners' helpers	231.5
Attendant labor	31.1
Bituminous-coal mining:	
Coal cutters and coal loaders	112.3
Attendant labor	3.9
Silverware manufacturing:	
Dusty processes	5.2
Non-dusty processes	1.7
Municipal dust (street cleaners):	
Congested district	4.1
Residential district	1.8
Cotton industry:	
Carding room	8.6
Weaving and spinning room	4.5

slate mills, talc and coal mining, and in the granite-cutting industry. Owing to the high percentage of quartz (35 per cent) present in granite, as compared with the dusts in the other industries listed in Table 2, granite cutting is revealed to be the most hazardous of the occupations we have studied.

A test of the value of any technique is in the results obtained in its practical application to a definite problem. Such a test was offered to us in the study of the health hazards of granite cutters in Vermont. In this study the following investigations were conducted for a period of slightly more than two years on a large group of workers: (1) Examination of the workers to determine

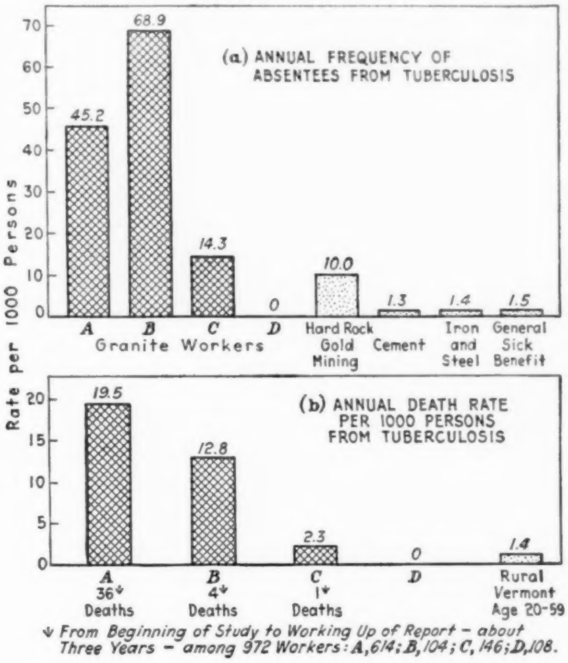


FIG. 5 (*a*) ANNUAL FREQUENCY OF ABSENCES FROM TUBERCULOSIS (EIGHT DAYS AND MORE). (*b*) ANNUAL DEATH RATE PER 1000 PERSONS FROM TUBERCULOSIS

their general physical condition; (2) special physical examinations to determine the prevalence of specific diseases of the respiratory system and the lung pathology resulting from exposure to granite dust; (3) record of the nature and severity of disabling illnesses; (4) occupational mortality statistics; (5) autopsies; and lastly (6), detailed studies of the nature and quantity of the dust exposure in each occupation.

Let us briefly examine the results of this study. The whole group of workers was divided into four subgroups, depending on their average dust exposure. Fig. 5 shows the annual frequency of absences due to tuberculosis and the annual death rate per 1000 persons from tuberculosis among the workers in these four groups. This figure also compares this data with similar information for other industrial groups.

In group A, which included hand pneumatic-tool operators and in which the exposure averaged about 59

(*Continued on page 262*)

SOCIAL TRENDS:

With Incidental Reference to Their Implications for Engineers

By EDWARD EYRE HUNT[1]

THE relationship between technology and sociology has implications not only for the leaders of engineering thought, but for the rank and file of the profession as well. Most engineering problems can no longer be considered apart from social problems, and whatever may be the current opinion as to the advantages or disadvantages of the machine to society, no one denies that the advance of technology creates a social problem or that the social order reacts upon the field of pure mechanics.

An instance of the relations between problems which will simultaneously arise both in the field of social science on the one hand, and in the realm of technology on the other, can be found in the fact that in the not distant future we shall have many more machines, and fewer people to use them. In our recent past, machines increased, but so did the population. If the multiplication of machines and the products of an advancing technology created social problems when the population of the United States was rapidly growing, what is to be anticipated by the middle of the present century when high authorities hold that we may have a population only about 18,000,000 larger than at present, with the proportion of younger members certainly declining, and that of the older men and women increasing.

POPULATION CHANGES AND THEIR PROBABLE EFFECTS

Statistics gathered by experts of the President's Research Committee on Social Trends appointed by Herbert Hoover in 1929, in the report made public in January of this year, disclose striking facts regarding population changes in the United States which bear significantly on plans for the future in which the engineering profession will have a stake. Without its being realized by the general public, the immigration-restriction policy of the Government along with the birth-control movement has already had a marked effect on the nation's population. The last census showed that the country had added 17,064,000 persons to the population between 1920 and 1930, the largest decennial increase in our history, or just as many people as we had in the whole country in 1840, but this rate of increase was considerably less than that from 1900 to 1910, or from 1890 to 1900. Emphasizing the fact that the trend of population growth is downward, the experts estimate an increase of only 10,000,000 or 11,000,000 by 1940, and another increase of only 8,000,000 to 11,000,000 by the middle of the century. The experts go even further and predict a maximum population perhaps as low as 146,000,000 in 1970, with a decline taking place thereafter.

Not less important than the slowing up in the growth of population is the decline in the proportion of children and youths in the population, already perceptible, and the corresponding increase in the number of elders. There were fewer American children under five years of age in 1930 than in 1920. It is estimated that in 1950 about 10 per cent of the people will be more than 65 years old, as against a proportion of little more than five per cent at present. In 1930, persons over 45 years of age represented 22.8 per cent of the total population, but in 1950 it is thought that nearly 30 per cent of the population will be more than 45.

While not addressed to engineers alone, remarks by the authors of the chapter on "The Population of the Nation" in the report of the President's Research Committee on Social Trends regarding the consequences of the "aging of our population" are pertinent: "In the past the nation has been noted for the readiness with which its business men have adopted new methods and scrapped valuable machines because of improvements which offered a chance to cut costs. Many other factors have also contributed to the efficiency of industry and commerce, but there is some reason to think that a part of this progressiveness has been due to the youth of the management and control.

"With the slowing up of population growth and the increase in the proportion of elders, there may also be a greater concern with the personal aspects of cultural life. Youth is more concerned with doing things, forging ahead, and making a place in the world. Age is apt to be more reflective, perhaps because the spur of poverty is less sharp, the inner driving force is weaker, or time and thought have brought about a change of ideas as to the goal of life. The mere shift in age distribution, therefore, may lead to more interest in cultural activities and increased support for the arts. Such developments in turn may influence the outlook and taste of the whole population."

ADJUSTMENT TO A SLOWER POPULATION GROWTH

Commenting further on matters more definitely related to engineering, the same authors write:

"An immediate and practical influence of slower population growth will probably manifest itself in efforts to adjust economic activity to such growth. In all likelihood this adjustment will not be particularly difficult in most lines, once business men are fully convinced that population growth will slacken and are able to estimate with fair accuracy the population for

[1] Executive Secretary, The President's Research Committee on Social Trends, New York, N. Y.

five or ten years in advance. That this change in attitude may not be easily effected is indicated by the fact that a population of from 200,000,000 to 300,000,000 by the year 2000 is frequently assumed by sales managers and executives. Just because the population in 1860 was eight times as large as in 1790, and in 1930 was four times as large as in 1860, one is not justified in saying that in 2000 it will be twice as large as in 1930.

"Certain industries will face difficulties and extensive problems in adjusting to a slower population growth; these will be the ones most affected by the probable future trends in population. They include industries in which technical improvements are rapidly increasing human efficiency, those in which consumption per capita is relatively inelastic, those in which productive capacity is already largely in excess of effective demand, and those in which capital (including land) is relatively durable, non-transferable, and has a high value per unit of product.

"Some industries, of which agriculture is an example, will be handicapped by a combination of several of these unfavorable factors. Farm production has been overexpanded since the World War, efficiency has increased rapidly, foods in general face an inelastic demand, and the proportion of capital in land is high, as is also land value per unit of product. Any policies for the utilization of farm land in the future must give careful consideration to the probable growth of population if they are to prevent the farm population from sinking to a low economic level.

"There are other industries which seem directly dependent upon population increase for their growth. These industries will feel the effects of an approaching stationary population in proportion to the degree they have a stable product or have already reached the saturation point. The present radio may be replaced by an improved model at any time, but the kitchen stove is usually kept until worn out. The point is that some industries can expect to expand only as population grows, even if purchasing power grows considerably."

PROBLEMS RAISED BY THE INCREASE IN MECHANICAL INVENTIONS

What may be accomplished in the near future in the field of mechanical inventions staggers the imagination and defies prophecy. In all spheres of activity—electricity, chemistry, physics, metals, power, transportation, construction, and machinery—we are only waiting for new opportunities to apply science to industry. In the decade between 1920 and 1930 more than 400,000 patents were granted in the United States alone. This is twice as many as were granted a half-century ago in the decade ending in 1890. In a review of findings, the members of the President's Research Committee on Social Trends, discussing the problems raised by the increase in mechanical inventions, state: "A larger proportion of work by machines and a smaller proportion of human labor are to be expected in the future. In 1870, 77 per cent of the gainfully occupied persons in the United States were engaged in transforming the resources of nature into objects of usable form through manufacturing, mining, and agriculture; in 1930, only 52 per cent. There are indeed a few cases of wholly automatic factories and automatic stores, and many automatic salesmen. Nor are the heavy productive machines the only ones which are increasing. The modern American surrounds himself with small tools and machines for personal use, such as the typewriter, the radio, the fountain pen, the toothbrush, the golf stick, the sunlight machine, and the ice-making refrigerator."

Discussing industrial technique and industrial organization in the face of increasing use of machines, the Committee states further: "The character of the work called for, its amount, the classes by whom it is performed, the materials used, the location of industrial plant, the capital investment, the selling methods, the prices of materials and products, the disbursement of wages, the profits made—these and a hundred subsequent matters are affected by improvements in machinery and industrial procedure. When the pace of technological progress is rapid, the business enterprises which grasp the new opportunities for gain bring to pass mass changes in economic conditions, and unwittingly produce a host of economic problems. All of these problems may be summed up in the question: How can society improve its economic organization so as to make full use of the possibilities held out by the march of science, invention, and engineering skill without victimizing many of its workers?"

RESEARCH ON RECENT SOCIAL TRENDS

Reference has been made in preceding paragraphs to the Research Committee on Social Trends which was set up by the President of the United States to carry on investigations into all phases of American life during the first third of the 20th century. It was the culmination of a series of studies which began with "Waste in Industry" in 1921 when Mr. Hoover was president of the American Engineering Council. Two other notable inquiries of special interest to engineers were made later, one on "Business Cycles and Unemployment," which reported in 1923, and "Recent Economic Changes," in 1929.

Since the attempt to study problems in terms of social areas rather than in terms of lines of policy is what has characterized these efforts, their results may be regarded as a kind of social cartography, the preparation of a series of maps showing elevations and depressions, backward areas and regions of rapid change—all to the end that we as a people may more intelligently and consistently plan and manage our future.

The American Engineering Council not only sponsored the first of these Hoover committees, it participated officially in the survey which led to the report on "Business Cycles and Unemployment," and two members of the Council—one of them a past-president—served on the staff which made the impressive report on "Recent Economic Changes."

The Social Trends Committee has also utilized engi-

neers, although the burden of carrying on the researches has been borne by sociologists and economists. This, the largest and the latest of the surveys, is a result of three years' work at an expenditure of half a million dollars provided by the Rockefeller Foundation. A staff of more than fifty was employed in the undertaking, and more than 700 organizations and individuals collaborated in the work. The report has been published under the title "Recent Social Trends in the United States," and thirteen supplementary monographs on a variety of subjects have appeared.[2]

The report emphasizes that most of our social problems arise out of the differential in rates of motion between related variables, adopting the view that mechanical invention and discovery are the pace makers in modern life. Opposing any idea of a scientific moratorium in order to permit the laggards to catch up, the President's committee suggests that social invention should be stimulated to keep pace more nearly with mechanical invention.

In general, the report presents a bewildering array of social problems emerging from the trends of the past third of a century, including in addition to those already discussed in this article, the problems of labor in society, of consumers, of farmers, and of other minority groups. The problems of the family and women and children follow, along with housing and education; the church; morals and social attitudes; and the problems presented by increasing leisure and the arts. Ameliorative institutions, private and governmental, are also stressed, with the problems of public welfare and social work, medicine and crime, growth and costs of government functions, relations of government to business, representation and laws, changes in the structure of government, and democracy and our relations with other nations.

The areas covered are so huge that any attempt to reduce the material to tabloid form would be to sacrifice essential portions. Much of the value of the work lies in its stress upon the interrelations among the parts of our social system, in the effort "to view the situation as a whole rather than as a cluster of parts." The survey turns up extraordinary material on the ways in which we make a living, the ways in which we amuse ourselves, the differences between city and countryside, the contrasts between economic organizations and disorganization, and the infinite variety of relations between government and society. The report bids fair to affect the future development of American society in countless ways, and to provide a bench mark or point of reference for all time to come.

[2] The Report and monographs are published by the McGraw-Hill Book Company, of New York. The titles of the monographs are: Population Trends in the United States; Communication Agencies and Social Life; Problems of Education in the United States; The Metropolitan Community; Rural Social Trends; Races and Ethnic Groups in American Life; Political, Social, and Economic Activities of Women; Labor in the National Life; Americans at Play; The Arts in American Life; Health and Environment; Trends in Public Administration; Growth of the Federal Government—1915–1932.

The Fermi-Dirac Statistical Theory of GAS DEGENERATION—I

With Some Applications to Electronic Phenomena in Metals

By VLADIMIR KARAPETOFF[1]

In this article, by applying the teachings of quantum mechanics, the author explains and discusses the following phenomena in metals: photoelectric effect, cold discharge, thermionic emission, magnetic susceptibility, electric and thermal conductivities, intrinsic difference of potential, and thermoelectric phenomena.

The article is essentially of an expository and rather elementary nature, dwelling upon the fundamental assumptions of quantum statistics, representative momentum space, the Pauli exclusion principle, and the probability of a state. After showing how certain assumptions lead to the concept of degeneracy of a gas, formulas are deduced for the kinetic energy of particles of a degenerate gas and for the specific heat at very low temperatures.

It is then shown that if an electron gas permeates a solid monatomic metal, the number of electrons being of the order of magnitude of the number of atoms, such an aggregate of electrons must be totally degenerate even at the highest temperatures attainable in the laboratory. A general picture is then drawn of the properties of such an electron gas permeating the space among the positive metal ions forming a stationary lattice. Electron spin is taken into consideration, and the general formulas of the Fermi-Dirac statistics are applied to this case. The concept of the mean free path is introduced and the distribution functions for electrons are explained, both for momenta and for energies. The conditions at the surface of the metal are discussed, and the necessity of assuming a potential "wall," in order to keep the free electrons within the metal, is explained.

I—INTRODUCTION

THE classical theory of perfect and imperfect gases, based on an older form of mathematical statistics, is largely a product of the middle of the nineteenth century with which the names of Boltzmann and Maxwell are prominently associated. While eminently satisfactory within the range of knowledge of behavior of gases that existed before the beginning of the present century, the classical form of statistics has gradually been found wanting in that, among other things, at very low temperatures the specific heat of a gas and some of its other properties have been shown to obey relationships entirely different from those set forth in the classical laws.[2]

About 1926, Fermi in Italy and Dirac in England published independently and almost simultaneously the principles of a new gas statistics, which later in the hands of Sommerfeld, Pauli, Fowler, Nordheim, and others has proved to be capable of useful applications to several baffling problems of modern electronic physics. In America, two general accounts of the Fermi-Dirac theory and some of its applications have been published.[3] Both of these are quite mathematical, and, in places, too concise for the general reader. The purpose of the author at this time is to present the fundamental starting points of the theory in as elementary a manner as is possible and to outline several of its applications without formal mathematical statements. The intention is to inform the reader as to "what it is all about," and to prepare him to read comprehendingly such articles as those by Bieler and Darrow. These latter in their turn are a preparation for a study of the original and more advanced contributions on the subject. No detailed literature references are given since a fairly complete bibliography of the original sources will be found in Darrow's article.

II—THE REPRESENTATIVE MOMENTUM SPACE

Consider a certain quantity of gas occupying a volume V and consisting of N identical molecules of mass m each. At a given instant each molecule possesses a definite vector momentum, $p = mv$, where v is the vector of the instantaneous velocity of the molecule. Imagine a fictitious three-dimensional

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[2] Other respects in which it was inadequate were: (1) On the assumption that the electric and thermal conductivities of a solid metal are due to certain motions of included electrons, and that these electrons behave like a perfect gas in a lattice of atoms, inadmissibly large theoretical values of specific heats of metals have been obtained by an otherwise apparently flawless reasoning. (2) The very principle of the quantum theory requiring finite, though very small, steps in the permissible values of the energy of the ultimate particles, necessitated a revision of the classical statistics in which no such limitation existed. (3) A change from the classical to a new quantum statistics has proved to be fruitful of results in the case of the theory of electromagnetic radiation, and enabled Bose to deduce Planck's radiation formula theoretically, using what is now considered to be quite rigid reasoning. (4) Pauli's exclusion principle, namely, that in a given atom there cannot be two or more electrons with the same values of all the quantum numbers, has proved to be quite successful in accounting for some previously puzzling facts of atomic behavior. It was therefore natural to try an extension of the exclusion principle to the behavior of molecules of a gas, especially at extremely low temperatures.

[3] E. S. Bieler, "The Fermi-Dirac Hypothesis of Gas Degeneration and Its Applications," *Jl. Franklin Inst.*, vol. 206 (1928), p. 65. Karl K. Darrow, "Statistical Theories of Matter, Radiation and Electricity," *Phys. Rev. Suppl.*, vol. 1 (1929), p. 114; and also *Bell System Tech. Jl.*, vol. 8 (1929), p. 700. See also a semi-popular lecture by R. H. Fowler on "The Passage of Electrons Through Surfaces and Surface Films," a 21-page pamphlet published in 1929 by the Oxford University Press.

SYMBOLS USED

a = thickness of potential wall, defined in Fig. 6
B = electric potential shown in Fig. 6
b = dimension indicated in Fig. 6
C = number of cells in a shell
C' = electric potential shown in Fig. 6
c_v = specific heat at constant volume
D = fraction of electrons which pass through the potential wall
d = degenerate; used only as a subscript
E = kinetic energy of a molecule
e = electronic charge
$\exp z = \epsilon^z$, where ϵ is the base of Napierian logarithms
F = distribution function in energy, defined by Eq. [23]
F' = same as F, but for electrons falling upon the metal surface
f = distribution function in momenta, defined by Eqs. [26] and [27]
G = intensity of electric field
g = electric conductivity of a metal
h = Planck's constant of action
K = a constant in Eq. [12]
k = Boltzmann's constant in Eqs. [12] and [13] and in the Appendix
l = mean free path of electrons
m = mass of molecule
N = number of molecules
N_0 = Loschmidt's number, that is, the number of molecules per gram-molecule
n = number of molecules or electrons per unit volume
P = gas pressure
P_0 = work function expressed in volts
P' = energy of fastest electrons in equivalent volts
p = vector momentum of a particle
$p_1, p_2, p_{12}, p_i, p_t$ = probabilities of events, see Eqs. [47]–[52]
Q = heat communicated; see Eq. [42] in the Appendix
R = universal constant for perfect gases; see Eq. [45] in the Appendix
r = radius of a sphere in the representative space
S = entropy of a gas
s_i = entropy of the ith portion of a gas
T = absolute temperature
t = total; used only as a subscript
U = density of emission current
V = volume of gas
V_1, V_2 = electric potentials in Eq. [41]
v = velocity of a particle
W = number of combinations, or thermodynamic probability of a state
w = volume of a cell in the representative space
α = a constant in Eqs. [10], [14], [16]
β = a constant in Eqs. [10] and [13]
θ = quantity defined by Eq. [17]
κ = heat conductivity of a metal
μ = frequency of electromagnetic radiation
Π = product of the terms it precedes.

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space (Fig. 1) in which all the p-vectors are plotted in their true directions from the origin. Such a space is called a representative momentum space, and the actual motions of the molecules of gas are indicated in this space by changes in the direction and magnitude of the momentum vectors. The assumptions which we are about to make will be introduced in this momentum space, and not in the real space occupied by the gas. These assumptions, justified only by the final results, are as follows:

(*A*) *Cells in the Representative Space.* Consider the representative space to be divided into a very large number of concentric spherical shells, the centers of all the spheres being at the origin O. Consider now the surface of one of these spheres, of radius p, and let it be ruled by any arbitrary curves into a large number of small equal areas. Draw radii from the origin to all the points of these curves and extend the radii to the next sphere, of radius $p + dp$. In this manner a large number of unit cells of equal volume, say, volume w each, will be formed in the spherical shell of thickness dp. Similarly, let all the spherical shells, from the radius zero to infinity, be divided into unit cells, the volume w of each cell throughout the representative space being the same.

The fundamental and rather revolutionary assumption will now be made that the representative space is *coarse grained*, a cell of finite volume w being the smallest distinguishable element within it. In other words, a cell of finite volume w takes the place of an infinitesimal element, such as $dxdydz$, in the ordinary space. As one of the consequences of this postulate, we shall assume that, no matter at what point a vector of momentum may terminate within a cell, it will remain the same vector in so far as the present theory is concerned. Thus in the cell Q (Fig. 1) two vectors of equal length but of different directions are shown. For our purposes they will be considered as one and the same vector. This does not imply a modification in the definition of the term "vector" as a directed quantity, but only a limitation of the accuracy with which one direction may be distinguished from another. If the accuracy of a geodetic instrument is one minute in angular measure, then two objects whose real angular distance is 10 seconds will be recorded as lying on the same line. Thus in the Fermi-Dirac statistics two vectors differing from each other so little in magnitude and in direction as to fall within the same cell need not be (or even cannot be) recognized as two different vectors. In cell M the three vectors of different direction and magnitude are also to be considered indistinguishable from one another. The same applies, of course, to the third dimension—not shown in the sketch. This assumption is equivalent to saying that if the velocity vector of a molecule changes so little that the end of the vector of momentum remains within the same cell, such a change in velocity is not recognized in the Fermi-Dirac statistics.

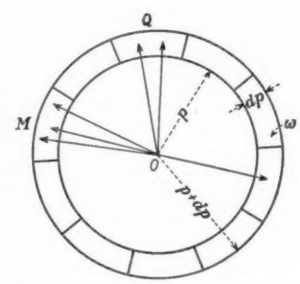

FIG. 1

However strange the foregoing assumption may seem, it is in accordance with the general spirit of discontinuity in the quantum theory which has accounted for so many known phenomena for which the classical theory of continuous changes gave results not in agreement with experimental data. The fundamental idea of quantization, that is, of small though finite steps in permissible changes in momentum, energy, vector direction, etc., has been firmly established in modern physics, and the foregoing picture of cells in the momentum space is but one of its forms.

Two comparisons or analogies suggest themselves. One is that of a guest in a hotel room. He is associated in the hotel records with that room, and the management does not take cognizance of his movements within the room. Another analogy is that of parts in mass production which have passed

inspection by gages. If the specification of a shaft calls for 1 inch diameter, with a tolerance of ± 0.005 inch, then the pieces whose actual diameters lie between 1.005 and 0.995 inches are still called one-inch size, and in the further assembly no cognizance is taken of the actual discrepancies.

(*B*) *Size of Unit Cells*. Let h be the so-called Planck's constant, or quantum of action. For our present purposes it is sufficient to state that it is a universal physical constant, in the same category with the velocity of light, electronic charge, etc. Its value depends upon the mechanical units used and may be found among various tabulations of physical constants. Its dimensions are those of "action," that is, energy times time, or momentum times length. The assumption (to be justified shortly) made in regard to the cells in the representative momentum space is that the volume of each cell is

$$w = h^3/V = (\text{Mom.} \times L)^3/L^3 = \text{Mom.}^3 \ldots\ldots [1]$$

where V is the actual volume of the gas in the real space. First of all, Equation [1] must be correct dimensionally. $(\text{Action})^3 = (\text{momentum})^3 \times (\text{length})^3$. Hence the dimensions of the right-hand side of the equation are those of $(\text{momentum})^3$. These are also the dimensions of w, because it represents a volume in the momentum space.

As to the assumption itself, it has to be justified by the results. Of course w must be inversely proportional to V, because the greater the total number of molecules, the smaller the "tolerance" which the momentum vector of each may have in the representative space; that is, the smaller the volume w. The factor h^3 makes for the correct physical dimensions, but whether the numerical factor preceding h^3/V is 1 or 1000 is another question, and the assumption that this factor is 1 is justified only by the final results. True, Equation [1] can be deduced on the basis of de Broglie's waves, which are supposed to accompany motions of material particles, but, after all, wave mechanics itself is a hypothesis, so that [1] may just as well be a starting point, a postulate.

(*C*) *Number of Vectors per Cell*. One of the important postulates of the modern quantum theory is the so-called Pauli exclusion principle. In its original form it was stated as follows: Not more than one electron within an atom can be associated with each set of four quantum numbers which characterize an electron. Extended later to molecules of gas, it forbids the existence of more than one molecule whose momentum at a given instant can be represented by a given vector in the momentum space. In other words, not more than one vector can terminate at a given instant in a given cell, and many cells must remain empty some of the time.

In Fig. 1 two vectors are shown in one cell and three in another for purposes of illustration only, as not in accord with Pauli's principle. If the momenta of some two molecules of gas at a certain instant of time should be found to be represented by two vectors both of which terminate in cell Q, then either there was an error in the measurement or else Pauli's exclusion principle is not valid.

At ordinary temperatures, Pauli's principle imposes practically no limitations upon the possible velocities of molecules, because of a high probability that any arbitrarily given momentum vector will terminate in an empty unit cell and therefore be permissible. In this respect the properties of a gas at ordinary temperatures are practically the same according to the Fermi-Dirac theory as, according to the classical kinetic theory, no limitations are imposed a priori on the existence of momenta of any value.

The difference becomes perceptible only at extremely low temperatures, because as the magnitudes of the individual momenta decrease, the cells near the origin become more and more occupied. At the absolute zero, all the cells nearest the origin are occupied by vectors of momenta and the gas is said to be completely degenerate. To account for all of the particles of gas, certain vectors of momenta must be of considerable magnitude in order to extend to empty cells, and their corresponding molecules must therefore possess finite momenta. Thus the gas itself remains endowed with a certain amount of energy, called the "zero-point energy," whereas, according to the classical theory, the energy of the gas becomes equal to zero.

Consider, for example, one cubic centimeter of hydrogen at 0 deg C and atmospheric pressure, containing 2.7×10^{19} molecules. The size of each cell in the representative space may be computed from Equation [1] and the cells themselves arranged in concentric spheres, the radius of each sphere being the value of a momentum, in gram-centimeters. Let now the gas be cooled down to almost the absolute zero of temperature, keeping the volume constant. Practically all the cells near the origin will be occupied, so that it is possible to estimate the radius of the sphere needed to accommodate all the 2.7×10^{19} molecular momenta within it. This will give an idea of the magnitude of the highest molecular velocities which must exist near the absolute zero, if Pauli's exclusion principle holds true.

A far-reaching consequence of the cell theory of the representative space is that a confined aggregation of electrons (if it be conceived of as an electron gas which obeys the Fermi-Dirac statistics) must be completely degenerate even at the highest temperatures at present obtainable in our laboratories. Computations show that an electron gas should begin to obey the laws of ideal gases at temperatures of the order of 50,000 C. To visualize this conclusion, consider a mixture of hydrogen molecules and electrons in thermal equilibrium with each other, at a temperature so high that the electron gas behaves like an ideal gas. The velocities of the individual particles of each gas vary between zero and infinity, according to the Maxwell-Boltzmann law. For the sake of simplicity, replace all these velocities for each gas by an average velocity such that the total kinetic energy of the gas remains the same. Since the kinetic energy is proportional to the square of the velocity, such an average velocity is sometimes known in the kinetic theory of gases as the quadratic average velocity, or the "square root of the average squared velocity." Assume the law of equipartition of energy to hold true, that is, the value of mv^2 for electrons to be the same as for H_2 molecules. A hydrogen molecule has a mass of about 3600 times that of an electron. Let the quadratic average velocity of hydrogen molecules be 1 and that of electrons v. Then

$$3600 \times 1^2 = 1 \times v^2$$

from which $v = 60$, or the average velocity of the electrons is 60 times greater than that of H_2 molecules. Yet the momentum p for H_2 particles is $p_H = 3600 \times 1 = 3600$, whereas for an electron, $p_e = 1 \times 60 = 60$.

Thus, assuming the hydrogen gas and the electrons to be at the same temperature, the momentum vectors of the H_2 molecules will mostly occupy cells remote from the origin, leaving the greater number of the cells empty, whereas the momentum vectors of the electrons will occupy the cells near the origin. The electron gas is degenerate, whereas the hydrogen is very far from degeneration.

Since gas temperatures are proportional to the average kinetic energy of molecules, increasing the average momentum of the electrons 60 times (to bring it to that of H_2 particles) would raise the temperature 3600 times. More accurate computations, on the basis of the criterion of degeneracy deduced from the Fermi-Dirac statistics, show that the degree of de-

generacy of helium at 5 deg absolute corresponds to the degeneracy of electrons at 36,000 deg absolute, for an electron gas containing the same number of particles per unit volume as the helium.

III—THE FUNDAMENTAL EQUATIONS

Consider again a very thin spherical shell in the representative space, between the radii p and $p + dp$ (Fig. 1). The volume of this shell[4] is $4\pi p^2 dp$. Since the volume of a unit cell is given by Equation [1], the number of cells in the shell is

$$C(p, dp) = 4\pi p^2 dp V/h^3 \quad [2]$$

The expression (p, dp) in the left-hand member of the equation means "at p, over the range dp." A mathematician may object to the use of C instead of dC in the same member, since the right-hand member contains dp. However, in physical problems involving discrete ultimate units of matter, electricity, radiation, or space, differentials are sometimes used in a sense quite different from that obtaining in classical physics or calculus, where a parallelpiped-shaped "box" $dxdydz$ cut out of a continuum can be imagined to be smaller than any specified small volume. In modern quantum physics, a box $dxdydz$ must contain a very large number of particles or unit cells, each of which is of finite magnitude. We thus have an apparent paradox of finite quantities being smaller than infinitesimals.

The explanation lies in the fact that we ordinarily use the differential calculus for continua only, whereas in this particular problem we have a large aggregate of elementary particles at small distances from one another, and even "infinitesimal" changes must comprise many such particles or unit cells. For example, in order for an infinitesimal volume $dxdydz$ within a gas to behave like a real gas of definite pressure and temperature (and not like a system of a few free material points), it must contain a large number of gas molecules. In other words, the *microscopic* structure of the gas is discontinuous, and only formulas of permutations and combinations can be applied to it. The *macroscopic* structure is continuous and can be treated by means of derivatives and differentials. The same explanation applies to our representative space in which unit cells constitute a fine discontinuous structure, whereas the structure of concentric shells is a rougher continuum to which the infinitesimal calculus may be applied.

For our purposes C has to be expressed in terms of the kinetic energy E of the molecules. We have

$$E = mv^2/2 = m^2v^2/2m = p^2/2m \quad [3]$$

and also

$$dE = pdp/m \quad [4]$$

Eliminating p and dp from [2] by means of these equations we obtain

$$C(E, dE) = (V/h^3)^3 2\pi(2m)^{1.5}E^{0.5}dE \quad [5]$$

Just as C in Equation [2] gives the number of cells or "momentum states" at p over the region dp, so C in [5] denotes the number of "energy states" at E over the range dE. One can conceive of a different representative space with concentric shells having values of E instead of p as radii.

[4] This expression for the volume of the shell is obtained by multiplying the surface of the sphere within the shell by the thickness of the shell. This is permissible in view of the fact that the thickness of the shell is infinitesimal. The ordinary expression for the volume of a shell, namely, the difference between the external sphere and the internal sphere, gives the same result as the expression used here if the squares of the infinitesimal quantities are neglected.

While C gives the total number of possible energy states (over the range dE) at E, this does not mean that the quantity of gas under consideration necessarily has at least one molecule for each of these states. Many possible states or cells may be empty. Let N be the actual number of molecules whose kinetic energies at the instant under consideration lie within the range of E and $E + dE$. In accordance with the Pauli exclusion principle, N cannot be greater than C. The number of ways or combinations in which these N molecules can be distributed among the C states is

$$W = C!/[N!(C - N)!] \quad [6]$$

This is the familiar formula for the number of combinations of a total of C objects, in groups of N objects, the order of the objects being immaterial. For example, let there be three cells ($C = 3$) and two particles to be placed in them ($N = 2$). Denoting these particles by a and b, and assuming at first that they are distinguishable from each other, we obtain Table 1.

TABLE 1

1	2	3
a	*b*	0
b	*a*	0
a	0	*b*
b	0	*a*
0	*a*	*b*
0	*b*	*a*

In this table a zero means that the corresponding cell is empty. Now let the particles be indistinguishable from each other, or else let the order in which they are placed in certain cells be immaterial. Then Table 1 reduces to Table 2.

TABLE 2

1	2	3
x	*x*	0
x	0	*x*
0	*x*	*x*

Here x means an occupied cell and 0 an empty cell. The distinction between the particles a and b has disappeared.

By hypothesis, in Fermi's statistics only the conditions represented by Table 2 are considered to apply; hence Equation [6] may be used. Substituting $C = 3$ and $N = 2$, we obtain $W = 3$ for the number of combinations; this is in accordance with Table 2.

Let N_t be the total number of molecules in the gas under consideration and E_t their combined kinetic energy. Both N_t and E_t are assumed to be known constants. We then have the following two conditions.

$$\Sigma N = N_t \quad [7]$$

$$\Sigma NE = E_t \quad [8]$$

where N represents the number of molecules possessing a kinetic energy within the limits E and $E + dE$ corresponding to an individual concentric shell in the representative space.

The next step is to compute the total number of "microscopically" distinguishable possible states of the gas, characterized by certain given values of N_t and E_t. The assumptions made are that the molecules are indistinguishable from one another, but that the cells within a shell in the representative space are distinguishable (because they correspond to different momentum vectors). This means that merely interchanging two molecules, say, a and b in a given state, does not give rise to a new state, but that moving a molecule, say, from cell No. 5 to an empty cell No. 6 within the same shell gives a new distinguishable state.

Let a certain arrangement of the molecules (and of the vectors of momentum) be kept stationary in all the shells except the one under consideration. Then the number of distinguishable states of the gas, corresponding to the same total energy, is given by the expression [6]. Now make a change in another shell—for example, move a vector of momentum from one cell to another, and with the new position of this vector again produce all the possible combinations in the first shell. We then shall again have W distinguishable states of the gas, all different from the previous ones, because we have disturbed a vector in the second shell. If the total possible number of arrangements in the second shell is W', then the total number of states of the gas, in so far as changes in the two shells only are concerned, is WW'. Reasoning in this manner over all the shells we find that the total number of distinguishable states of the gas is

$$W_t = \Pi W \qquad [9]$$

where the symbol Π denotes "the product over all the shells," and W is given for any shell by Equation [6].

The quantity W_t, called the *thermodynamic probability* of a state, indicates the number of ways in which that particular state can be realized. As time elapses, the agitation of the molecules brings about different combinations of velocities and momenta and consequently new states, but that state which is realizable in the greatest possible number of different ways will occur more frequently than any other. Detailed computations show that with a very large number of molecules, the actual average state of the gas is almost indistinguishable from the most probable state.

Thus, mathematically speaking, the problem of determining the actual microscopic or detailed condition of a gas is reduced to finding the values of N for each shell which will convert expression [9] into a maximum, with the limitation that these values of N must satisfy conditions [7] and [8]. This is a perfectly definite problem in relative maxima and minima into a solution of which we shall not go here, since the method has been treated in detail in some of the sources referred to in the articles quoted in footnote 3. The result is that for any shell containing C cells and corresponding to an amount of kinetic energy E per molecule, the number of molecules which will convert expression [9] into a maximum is

$$N = C/[\exp(\alpha + \beta E) + 1] \qquad [10]$$

where α and β are certain undetermined constants and C is given by Equation [5].

IV—THE FINAL FORMULAS

To determine the factor β in Equation [10], substitute for C its value from [5]. The result is

$$N = (V/h^3)2\pi(2m)^{1.5}E^{0.5}dE/[\exp(\alpha + \beta E) + 1] \qquad [11]$$

Previous to the introduction of the Fermi-Dirac statistics, when the classical kinetic theory of gases was the only one known, a different system of statistical reasoning was used, based on "distinguishable" molecules, and the following formula derived:

$$N = KE^{0.5}dE/[\exp(E/kT)] \qquad [12]$$

In this expression K is a constant with whose value we are not concerned here; T is the absolute temperature of the gas, and k is the so-called Boltzmann constant, well known in the classical thermodynamics and in the modern atomic theories. In view of the importance of the constant k, its derivation and meaning are given in the Appendix.

Within the range of temperatures and pressures at which a real gas behaves like a perfect gas (high temperatures, low densities), all working formulas deduced on the assumption embodied in [12] check well with experimental data, so that that equation may be assumed to be true at high values of E. Under these conditions Equations [11] and [12] must give identical results. We therefore neglect the term 1 within the brackets in [11], and, in order that the dependence of N on E shall be the same in [11] and [12], impose the condition that

$$\beta = 1/(kT) \qquad [13]$$

Another way of proving [13] is to assume that the relationship [52]—in the Appendix—between the entropy and the thermodynamic probability of state, postulated in the classical kinetic theory of gases, also applies to the new thermodynamic probability expressed by Equations [6] and [9]. Proceeding then with the usual definition of entropy, $dS = dE/T$, will lead to an exponential expression of the form [10] with the same value of β as that given by Equation [13].

To evaluate α, the expression for N is substituted from [11] in the left-hand members of [7] and [8]. The summation is then replaced by an integration with respect to E between the limits zero and infinity. The purely mathematical part of the operations is quite involved, necessitating expansions into infinite series. Therefore only the final results which are of interest will be given.

a Large positive values of α have been shown to correspond to temperatures and densities at which the gas is not degenerate but behaves like a perfect gas of the classical thermodynamics. Thus this case is of no practical interest because under such conditions the old classical formulas are entirely adequate. It is merely sufficient to show that in this case the result obtained from the Fermi-Dirac statistics checks with the corresponding classical formula. By the method outlined above we obtain:

$$\exp \alpha = V(2\pi mkT)^{1.5}/(N_t h^3) \qquad [14]$$

and

$$E_t = 1.5N_t kT \qquad [15]$$

Comparing the latter formula with the classical expression [55] in the Appendix, it is seen that the two are in agreement.

b When there is strong degeneration in the gas, modifying its usual properties, α may be shown to assume large negative values. This is the range in which we are interested, because it is under these conditions that the classical theory fails. Actual computations show that in this case α may be represented by an infinite series of the form

$$\alpha = -(1/\theta T)[1 - (\pi\theta T)^2/12 + \text{etc.}] \qquad [16]$$

where, for the sake of abbreviation,

$$\theta = 8(\pi V/6N_t)^{2/3}(mk/h^2) \qquad [17]$$

Using this value of α in the expression for the total kinetic energy of the gas, E_t, we obtain an approximate result of the form

$$E_t = 0.6(N_t k/\theta)[1 - (\pi\theta T)^2/12 + \text{etc.}] \times [1 + (\pi\theta T)^2/2 + \text{etc.}] \qquad [18]$$

From this formula the following two important expressions can be derived for a degenerate gas. In [18] put $T = 0$; then the so-called *zero-point energy* is

$$E_{T=0} = 0.6N_t k/\theta \qquad [19]$$

Actually perform the multiplication of the two series in [18] and disregard all the terms with the powers of T higher than

T^2. This will give an expression for E_t sufficiently accurate at very low temperatures. The factor θ may be used for any volume of gas. To apply the result to a unit volume, put $V = 1$ and $N_t = n$, where n is the number of molecules per unit volume. To change to the energy per gram-molecule, multiply the result by N_0/n, where N_0 (Loschmidt's number) is the number of molecules per gram-molecule. Finally, to obtain the *specific heat at constant volume per gram-molecule of degenerate gas*, take the derivative with respect to T of the foregoing expression for the energy. The result will be

$$dE_t/dT = c_{vd} = (4\pi/3)^{2/3}[\pi^2 N_0 mk^2 T/(h^2 n^{2/3})] \ldots\ldots [20]$$

Equations [18], [19], and [20] are interpreted graphically in Fig. 2, values of E_t being plotted against those of T as abscissas. The curve of specific heat, c_v, is not shown separately because $c_v = dE_t/dT$, so that the slope of the E_t-curve is proportional to the value of c_v at that temperature. It will be seen that when a gas is degenerate, the kinetic energy of agitation of its molecules does not approach zero but a finite limit, which is reached at $T = 0$. Moreover the specific heat at constant volume, far from being a constant quantity (as it is for a perfect gas), is proportional to T and becomes zero at $T = 0$.

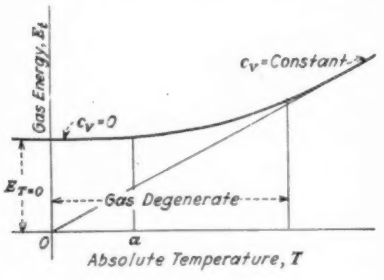

FIG. 2

These relationships were known experimentally for a number of years previous to the work of Fermi and Pauli, and also were derived by Nernst and by Planck from purely thermodynamic considerations and the observed behavior of gases at low temperatures. Sometimes this behavior at zero temperature (a horizontal tangent and a finite ordinate of the energy curve) is called the "third law of thermodynamics," or Nernst's heat theorem, and is stated as dogmatically as the first two laws—for example: "It is impossible to devise an engine which will completely deprive a body of its heat content, that is, cool it down to the absolute zero." The fact that the Fermi-Dirac statistics leads to results consistent with this law is another argument in favor of its soundness.

The existence of zero-point energy could have been predicted from the very basis of the Fermi-Dirac statistics, with its picture of unit cells in the representative space. As the temperature and the energy of agitation decrease, more and more cells near the origin become occupied. Since there are only a few cells right at the origin, corresponding to negligible energy or momentum, many vectors have to fall within cells more remote from the origin if the extension of the Pauli exclusion principle is to be satisfied. This means that even at the absolute zero many molecules of gas must possess appreciable energy.

In fact, the value of E in Equation [19] may be computed directly from a consideration of occupied cells in the representative space. Let r be the radius of the sphere within which all the occupied cells are located at $T = 0$. The volume of the sphere is $4\pi r^3/3$, and the volume of a unit cell is h^3/V. Hence, equating the number of cells to the number of molecules we obtain

$$(4\pi r^3/3)(V/h^3) = N_t \ldots\ldots\ldots\ldots\ldots\ldots [21]$$

To compute the total energy of such an aggregate, consider an infinitesimal shell of radius p (where p is smaller than r) and thickness dp. The number of cells in this shell is $(4\pi p^2 dp) \times (V/h^3)$, and the energy per molecule is $p^2/2m$. Hence

$$E_t = \int_0^r (4\pi p^2 dp)(V/h^3)(p^2/2m) = 0.4\pi V r^5/(mh^3) \,.\, [22]$$

To eliminate r from [21] and [22], raise both sides of [21] to the $^5/_3$ power and multiply the result by [22], term by term. The result will be Equation [19], which is thus proved by a different method.

(To be continued)

Society of Rheology Papers of Interest to Engineers

THE Society of Rheology held its fourth annual meeting in Atlantic City, December 27–28, 1932. In a symposium on the flow of solids, reports were presented on a wide variety of materials, including igneous rocks, cement and cement-mortar stone, and ductile metals.

Dr. Nadai, of the Westinghouse Electrical and Manufacturing Company, gave a report on the creep of metals under prolonged loading as carried out by him.

Dr. Robt. Balk showed many samples of rock which were examples of flowage in such material. Dr. Markus Reiner, of Lafayette College, showed beams of cement which had not only flowed enough for the phenomenon to be readily visible, but in which the flow continued for an indefinite time and at loads hardly greater than the weight of the beams themselves.

Dr. H. Hencky, of the Massachusetts Institute of Technology, has treated non-Newtonian liquids according to the relaxation theory of Maxwell. He has shown that two new coefficients are necessary to characterize the material.

Dr. J. R. Coe, Jr., has been working for over a year at the U. S. Bureau of Standards in order to determine the viscosity of water with an accuracy heretofore unknown. He has derived a method for improving the bore of capillary tubes of almost microscopic size which resembles and was in fact suggested by the method used by Dr. Rowland at Johns Hopkins in making spectroscopic gratings. It was necessary to have a screw more perfect than any known before, and Dr. Coe ground it to perfection in its nut. So here the capillary is made perfect by means of a wire which moves back and forth until it has worn down all of the "high spots." The second novel feature reported on was the fact that all timing of the flow in the ordinary sense is eliminated by an extremely accurate machine which forces through the capillary a given quantity of water each second.

Mr. M. R. Fenske and W. A. Herbst, of Pennsylvania State College, have made a study of the effect of chemical constitution upon the temperature coefficient of viscosity, which is a problem of great interest to the lubrication engineers. Dr. Dickinson and Dr. Bridgman of the U. S. Bureau of Standards presented a discussion on the subject of oiliness in lubricants.

(The foregoing has been prepared from material kindly supplied by Prof. E. C. Bingham, Secretary, Society of Rheology, and Dr. A. Nadai, of the Westinghouse Electric and Manufacturing Co.)

A Thermodynamic THEORY *for* STEAM?

By HENRY E. LONGWELL[1]

FOLLOWING the suggestion of a friendly critic, this paper is offered "not necessarily as a contribution to learning, but as a stimulus to thought." While marvelous advances have been made in the technique of steam research, we still cling tenaciously to theories which, on the average, are over three-quarters of a century old. Discussion of the basic soundness of these theories has been non-existent for many years. We accept them today in blind faith, and not by reason of any appeal to the intellect or the imagination. Possibly the time may be ripe for subjecting them to a critical examination, in the newer light which may have resulted from our more highly refined experimental work.

As a starting point, attention is directed to the following simple method of calculating, in English units, the specific volume of saturated steam from its total heat, temperature, and pressure. It works with conspicuous accuracy between the limits of 212 F and 450 F; or in terms of pressure, from 14.7 lb per sq in. to a trifle over 422 lb.

1. From the number of Btu *total-heat* content, subtract the temperature *less* 32 *deg*
2. Multiply the remainder by the temperature *plus* 310 *deg*
3. Multiply this product by 778.3, a number which is strongly reminiscent of the best average value of the mechanical equivalent of heat, expressed in foot-pounds
4. Divide the final product by 1,000,000
5. Divide the quotient by the pressure. The final quotient is the specific volume.

Testing this method of computation with the 1930 edition of Keenan's "Steam Tables," we get the following checks:

Temperature, deg F......	212	300	350	400	450
Computed volume.......	26.82	6.455	3.334	1.8604	1.1003
Keenan's volume........	26.82	6.464	3.338	1.8608	1.0997

This method checks equally well with the Goodenough tables: in fact it was developed by the use of these tables some years before the Keenan tables were published. It is quite probable that it checks substantially as well with any of the standard steam tables published within the past thirty years.

The most interesting feature of this method of computation is the *direct* relation between the product of pressure by volume, and the temperature. No series equations, involving unusual powers of the variables, or a multiplicity of arbitrary "constants," are required. The temperature scale, $T = t + 310$, is far removed from the Kelvin scale, more commonly known as the "Absolute" scale, in which $T = t + 459.6$. Consequently one thought that might be stimulated is, whether our faith in the universal applicability of the Kelvin temperature scale may not have hindered, rather than helped, our efforts to discover a logical basis for formulation.

As the temperature increased above 450 F, it was found that the volumes computed by the method outlined began to show a growing increase over the tabular values. This suggested that some refinements in the formulation were necessary. The bewildering differences in the tabulated properties of steam in the higher temperatures, as sponsored by various investigators, created such uncertainty as to where the true path might be located, that it was felt that any work along the line of refining this evidently crude method would be wasted; and for the time being the problem was allowed to rest.

OUTSTANDING ACCOMPLISHMENTS OF STEAM TABLE CONFERENCE

Happily, through the International Steam Table Conference this condition of uncertainty has been relieved to an extent that encourages renewed effort on the part of all who are interested in formulation. The outstanding accomplishments of the Conference are:

1 The adoption of the "Skeleton Steam Tables," in which "assumed mean values" for the several properties have been fixed at ten intervals, from 0 C to 350 C, both inclusive. Reasonable tolerances have been agreed upon which represent the maximum error that is likely to be found in the assumed mean values. This provides a definite mark at which to aim, and yet one not so narrow as to discourage us from making an attempt to hit it.

2 The adoption of a single energy unit—the International kilowatt-hour—which may manifest itself either in the form of heat or of mechanical work. This effectually disposes of all question as to the mutual equivalence of these two transformations of energy. The basic unit of heat, the International kilogram calorie, is fixed by definition as $^1/_{860}$ International kilowatt-hour.

The weights and measures used in the Skeleton Tables are naturally those of the metric system, since that system is used by most of the civilized nations of the world. Even among English-speaking people, the metric system is pretty generally regarded as a part of the universal language of science. The unit of volume used in the Skeleton Tables is the cubic meter; the unit of mass is the kilogram; the unit of pressure is one kilogram per square centimeter; and the unit of work is the kilogram-meter.

CONVERSION FACTORS

The Steam Table Conference is silent on the subject of conversion factors for evaluating heat units in terms of pressure-volume units, and vice versa. As these transformations seem to be essential to what we regard as "formulation," we must work out the conversion factors for ourselves.

A kilogram-meter is of course, the work done in overcoming a force of 1 kilogram through a distance of 1 meter. If we regard the force as being distributed over a plane surface having an area of one square centimeter, then we can visualize the picture of this surface being pushed in a direction perpendicular to itself, through a linear distance of one meter, thereby generating a volume of 100 cubic centimeters. This quantity of work is equal to 9.80665 joules, the joule being

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equivalent to 1 watt-second, which is one thirty-six hundred thousandth part of a kilowatt-hour. This unit might be designated more accurately as a "square centimeter meter-kilogram."

For thermodynamic computations based on the cubic meter as the unit of volume, we can visualize the "cubic meter-kilogram" as a plane surface 1 square meter in area, under a pressure of 1 kilogram per square centimeter, and generating a volume of 1 cubic meter by being forced in a direction perpendicular to itself through a linear distance of 1 meter. This cubic meter-kilogram is therefore 10,000 times as large as the unit considered in the preceding paragraph. Consequently its equivalent in joules is 98,066.5. The value of the International gram calorie being 4.1875 joules, it follows that the value of the International kilogram calorie is 4187.5 joules. Hence

$$1 \text{ cubic meter-kilogram} = \frac{98{,}066.5}{4187.5} = 23.419 \text{ kilogram calories.}$$

Reciprocally, 1 kilogram calorie = 0.0427 cubic meter-kilogram.

Approaching the problem from another direction, we have 1 kilowatt-hour = 367,225 kilogram-meters. Dividing by 860, we have 1 kilogram calorie = 427 kilogram-meters. This force of 427 kilograms, distributed over an area of 1 square meter, would represent a pressure of 0.0427 kilogram per square centimeter. Hence, as before, 1 kilogram calorie = 0.0427 cubic meter-kilogram; and reciprocally, 1 cubic meter-kilogram = 23.419 kilogram calories. We now have two important conversion factors, namely,

1 To convert cubic meters × kilograms per square centimeter into kilogram calories, multiply by 23.419.
2 To convert kilogram calories into cubic meters × kilograms per square centimeter, multiply by 0.0427.

A casual inspection of any of the recognized steam tables reveals the fact that practically every product of pressure by volume, at temperatures substantially below 450 F or 232 C, is duplicated at some temperature above this dividing line. This suggests that the product of pressure by volume is not determined by temperature alone, as in the case of a gas composed of free molecules, but by cooperation with some other factor.

Now, if we believe that the assumed mean values for the properties of saturated steam, as set forth in the Skeleton Tables, are closer to the actual values than are those in any individual table, and if an equation can be devised, such that by substituting the assumed mean values for temperature and pressure, and some function of the heat content, it can readily be solved for volumes, yielding over the temperature range from 100 C to 350 C results well within the approved tolerances, it would seem that such an equation should be worthy of reasonably serious consideration.

PROPOSED EQUATION RELATING THE TEMPERATURE OF SATURATED STEAM WITH OTHER OF ITS PROPERTIES

An equation which appears to meet those specifications, is submitted below:

$$\frac{p(V-0.001)}{L'} = 0.00001104854\,T' \qquad [1]$$

In this equation and the calculations that follow, the old-fashioned notation is used, on the assumption that it is probably more familiar to the average reader.

H = total heat of steam in kilogram calories
h = heat of the liquid in kilogram calories
L = conventional value of latent heat = $H - h$
p = pressure in kilograms per square centimeter
V = volume of saturated steam in cubic meters per kilogram
v = volume of saturated water in cubic meters per kilogram
T' = (t°C + 190), substituted for T = (t°C + 273.1)
L' = a corrected value for the conventional L = latent heat.

The temperature scale is the same as that used in the illustrative computation at the beginning of this paper, except that it has been translated from fahrenheit into centigrade degrees by dividing by 1.8, which is the ratio between the two thermometric scales. For example, on the fahrenheit scale the characteristic temperature corresponding to atmospheric pressure was given as 212 + 310 = 522 deg; dividing by 1.8, we get 290 deg = 100 + 190.

The conventional determination of L is an uncompleted experiment, in that the mass content of the calorimeter is not restored to its original state. At the end of the experiment there is left behind in the calorimeter a volume of saturated steam equal to the volume of saturated water actually evaporated. Were the experiment completed by introducing into the calorimeter a mass of saturated water equal to the mass evaporated, all of the steam would be expelled. This would require the expenditure of additional energy, equal in amount to the thermal equivalent of pv; that is to say, $L' = L + 23.419 \times pv$. At temperatures up to 150 deg this correction is so small as to be insignificant. Above that point it increases rapidly, and at 350 deg it amounts to more than 3 per cent.

This undervaluation of L is due to the failure to realize that a part of the so-called "heat of the liquid" is latent. A cursory glance at any of the steam tables shows clearly that increase of volume is characterized by increase of latent heat. On raising the temperature of 1 kilogram of water from 0 deg to the critical point, its volume increases to three times its original dimensions; and in doing so it has to overcome an external pressure of 225 kilograms per square centimeter. Is it not probable that a considerable amount of the heat supplied becomes latent by reason of its conversion into work? And does it not seem strange that "thermodynamic consistency" requires us to assert that at the critical point the latent heat vanishes altogether.

Another reason for suspecting the integrity of the conventional values of L is revealed in the later interpretations of the Clapeyron relation by the Bureau of Standards investigators, and in those of the Massachusetts Institute of Technology. These interpretations are not open to criticism. From the mathematical standpoint they are unimpeachable. They show most clearly that we cannot, except at very low temperatures, use the conventional latent heat of 1 kilogram of steam as a basis for computing its volume by means of the Clapeyron relation. At 200 deg we must take the latent heat of 1.009 kilograms of steam; at 250 deg the ratio is 1.0256 to 1; at 270 deg, the upper limit of the Bureau of Standards experiments that have been communicated to the public, the ratio is 1.038 to 1. Assuming that the mean values of the Skeleton Steam Tables are actual values, the basis for computing the volume of 1 kilogram of steam at 350 deg would be the conventional latent heat of practically 1.25 kilograms of steam.

HOW COMPUTED SPECIFIC VOLUMES COMPARE WITH SKELETON-TABLE VOLUMES

Table 1 shows how the specific volumes computed by the equation compare with the assumed volumes given in the Skeleton Tables. Column 2 gives the Skeleton Tables volumes against the respective temperatures. Column 3 gives the computed volumes. Column 4 gives the differences between the tabular and the computed volumes. Column 5 gives the volume tolerances as approved by the International Steam Tables Conference. Volumes are stated in terms of cubic meters per kilogram.

It will be observed that the computed volumes all lie well

TABLE 1 COMPARISON OF ASSUMED SPECIFIC VOLUMES OF SATURATED STEAM FROM INTERNATIONAL SKELETON STEAM TABLES, WITH SPECIFIC VOLUMES COMPUTED BY EQUATION $p(V - 0.001)/L' = 0.00001104854\ T'$

Temperature, deg C	Specific volume, Skeleton Tables, cu m per kg	Specific volume by equation, cu m per kg	Difference ±, cu m per kg	Skeleton Tables mean tolerance, cu m per kg
350	0.00875	0.00870	−0.00005	±0.00020
325	0.0142	0.0143	+0.0001	±0.0004
300	0.0215	0.0219	+0.0004	±0.0005
275	0.0329	0.0331	+0.0002	±0.0005
250	0.0502	0.0502	0.0000	±0.0004
200	0.1273	0.1270	−0.0003	±0.0004
150	0.392	0.392	0.000	±0.001
100	1.673	1.673	0.000	±0.002

NOTE. For the purpose of evaluating the constant of the equation, the volume at 100 deg is assumed to be exactly 1.673 cu m per kg.

within the tolerance limits. In no instance has advantage been taken of the approved tolerances for any of the properties other than volume, unless the redistribution of the total heat, resulting from the latent-heat correction, may be regarded as such.

ILLUSTRATIVE CALCULATION OF SPECIFIC VOLUME OF SATURATED STEAM

A sample calculation of the specific volume at 350 deg, based on the Skeleton Tables data, is given below.

Latent-Heat Correction.

v =	0.00174 cu m per kg	log = −3.2405492
p =	168.7 kg per sq cm	log = 2.2271151
Conversion factor =	23.419	log = 1.3695683
pv = correction =	**6.874** kcal per kg	log = 0.8372326
H =	615 kcal per kg	
h =	404 kcal per kg	
L =	$H - h$ = 211 kcal per kg	
pv = correction =	6.874	
L' =	**217.874** kcal per kg.	

Computation of V. For convenience and accuracy it is best to convert Equation [1] to the logarithmic form:

$$\log (V - 0.001) = \log 0.00001104854 + \log L' + \log T' - \log p$$

Constant =	0.00001104854	log = −5.0433050
L' =	217.874 kcal per kg	log = 2.3382054
T' =	540	log = 2.7323938
$p(V - 0.001)$ =	1.2999 cu m-kg	log = 0.1139042
p =	168.7 kg per sq cm	log = 2.2271151
$V - 0.001$ =	0.00770 cu m per kg	log = −3.8867891
	0.001	
V =	**0.00870** cu m per kg	

Equation [1] bears a marked resemblance to the gas equation $PV = RT$. In both equations the right-hand member is the product of a constant multiplied by temperature. In the left-hand member of the proposed equation, the volume factor is not the *total* volume but the *increase* over the minimum observed volume of 1 kilogram of water in a natural state of equilibrium. The outstanding departure from the gas equation is the introduction of a quantity of latent heat, sufficient not only to evaporate the water, but in addition to deliver *all* of the steam outside of the vessel in which it is generated. No matter how much steam we may have *inside* a boiler, it is unavailable for use until it is delivered through the boiler outlet; and this delivery requires the expenditure of energy.

Some explanation is due the reader for the seeming radicalism of substituting the temperature scale $T' = t + 190$ for the so-called "absolute" scale, $T = t + 273.1$. The latter agrees, unquestionably, with the pressure changes of a reasonably perfect gas when subjected to changing temperatures. This was determined by careful experimentation over eighty years ago. How this particular scale came to be universally accepted as "absolute," and applicable to thermal changes in all substances, is difficult to comprehend.

CONCERNING ABSOLUTE ZERO OF TEMPERATURE

An absolute zero of temperature is just as inconceivable to the human mind as the beginning of time or the end of space. Our knowledge of physical facts concerning any and all things in the universe is relative to arbitrary standards. Absolute knowledge we do not have, nor can we ever hope to acquire it. As regards thermodynamic temperature scales, it seems reasonable to suppose that every substance whose physical characteristics change with changes in temperature has a natural thermodynamic scale of its own. At least, such a hypothesis appears to be worth investigating.

The Clapeyron equation is often cited as proof of the validity of the absolute-temperature theory; but this equation was devised in 1834, fourteen years before the promulgation of the absolute-temperature doctrine. Its original form was

$$LF't = (V - v)\,(dp/dt)$$

$F't$ was merely an undetermined function of the ordinary temperature scale. It was not until 1848 that this function was evaluated in terms of absolute temperature and Joule's mechanical equivalent of heat, at the suggestion of Prof. William Thomson, the brilliant young man who was destined to become, forty-four years later, Lord Kelvin.

An important point to be borne in mind is that the measured pressure of steam is not its real or thermodynamic pressure. It is merely the excess of the real pressure over the force required to balance the attraction which the molecules exert on each other. This is the equivalent of an "internal-work pressure" as conceived by Prof. James H. Cotterill, and expounded in his textbook entitled "The Steam Engine Considered as a Heat Engine" (edition of 1878). Most unfortunately, this helpful concept was ignored by practically all of Cotterill's contemporaries and their successors, and is now well-nigh forgotten.

Another matter requiring caution is the tendency to assume that because heat and energy are *mutually convertible*, they are *identical*.

The author has endeavored to make this presentation in such a way that the practical engineer, who feels that he has no time for theoretical papers, may not find it a boresome task to follow the simple, direct line of reasoning, or the conspicuously elementary mathematical treatment.

An effort has been made to create a mental picture of the product of volume multiplied by pressure; and to show that it is not, as at first thought might be feared, an adventure into the mystical realm of "four-dimensional space."

The formula developed, while decidedly unconventional, has at least the novelty of indicating a direct relation between the temperature of saturated steam and its physical properties.

If this paper shall provoke any frank and open discussion it will have served a useful purpose, and even though discussion in its earnestness may at times become a bit acrid, it is nevertheless the most effective instrument we have for uncovering new truths or for burying old errors.

The Significance of
SPEED STANDARDIZATION

By J. DECKER[1] and W. P. ACRES[2]

DURING the past quarter of a century it has become increasingly evident to the industrial world that standardization is essential. A nut produced in the East must mate with a bolt threaded in the West, a valve made by one manufacturer must be capable of being bolted to a flange forged by another. Not only has the trend toward recognized national standards been prompted by the necessity of interchangeability, but also by the vast economies in manufacture to be realized through the adoption of standard dimensional specifications. Mass production with all its attendant economies could only thus be had.

The many economic advantages of dimensional standards are obvious, and great progress has been made in their development and acceptance by industry. Standard dimensions for many manufactured products have already been established, and others are in the process of development. Almost as obvious are the advantages to be gained through standardization, to some degree, of the machines required to furnish power for the manufacture of these standard products and of the driven machines of all kinds that actually produce them. In this field, too, we find that notwithstanding that much has been accomplished, the economic possibilities of standard *speeds* for these machines have, until recent years, received but scant consideration.

Here in this inobtrusive element, speed, lies a tremendous opportunity for saving in production costs; an opportunity which is slowly but surely gaining world-wide recognition.

THE MOVEMENT TO STANDARDIZE MACHINE SPEEDS

In the United States this recognition is evidenced in the activities of a committee on the standardization of speeds of driven machines organized late in 1930 under the sponsorship of the A.S.M.E. In Europe, mainly through the successful pioneer work of Dr. Ing. G. Schlesinger, a large portion of German industry has adopted standardized speeds. France also is following suit, and in May, 1932, the International Standards Association recommended the German series of speeds for adoption as an international standard. German machine-tool builders are today stressing the fact that their machine speeds are based on a standardized series. A tool of one make may be replaced by that of another without alteration in the drive. A machine bought today may be supplemented in a few years by another, with all the advantages of uniformity in drive and rate of production. The numerous diameters of pulleys formerly required are fast becoming fewer. The economies to be effected through standardization of speed are no mere speculation.

American industry could benefit equally by such a procedure and at the same time profit by the experience of Europe under the leadership of Germany. On a competitive basis, American manufacturers of machine tools, for instance, cannot afford to have their products lack any features that others are able to use as outstanding sales arguments.

ECONOMIC DESIRABILITY OF STANDARDIZED SPEEDS

Competition among the builders compels the individual manufacturer to have his product differ in almost every respect from that of his rival. The user's difficulty in running a number of machines now increases in proportion to the number of different makes of the same class of machine installed. Often it is found to be more economical to install an inferior machine provided it will meet the specifications for maximum and minimum speeds, range of speed, number of subdivisions of speed, or ratio of speed drop of the existing equipment.

Great variation in the speed drop or geometrical speed ratio between machines of the same class and type results of necessity in uneven quantity output. This in itself might not be a serious factor were it not for the numerous contingent expenses such as the necessity of more careful supervision and control, the proportional increase in time study, difficulty of rate setting, added estimating labor with accumulating clerical work, and the potential labor difficulties arising through piece-work-rate disputes.

However, if any system of standardized speeds is to be set up and successfully applied it must cover the whole field of production machinery and must be constructed in such a way that any particular industry can select its own standard series and still be in harmony with the whole.

The problem is not a simple one, yet, as in the case of most complex problems, it is capable of a rational and orderly solution. First, some system of numbers must be found, each of which will bear to its neighbor such a relationship that, whether in the range of high speed or low, an adequate selection of evenly graduated speeds may be available. Secondly, the relationship between succeeding speeds must be simple. Thirdly, the system must be capable of expansion to give greater or lesser intervals between succeeding terms and yet retain in these expanded or contracted series a flexible, geometrically graduated sequence.

ADVANTAGES OF THE "40" PREFERRED-NUMBER SERIES IN FORMULATING STANDARD SPEEDS

To meet these conditions on a purely mathematical ground the so called "40" series of A.S.A. preferred numbers immediately recommends itself as the master or selection series. In this series each term multiplied by $\sqrt[40]{10}$ or 1.06 produces the next succeeding term and results in a decimal-geometric series repeating in every decade with forty terms in each cycle. This simple repetition lends itself readily to the determination of an ideally graduated series of numbers over an unlimited range with a minimum of effort, every term in a given decade being ten times the corresponding term in the preceding decade. Upon further inspection we find that every second term in this "40" series bears the ratio $\sqrt[20]{10}$ or 1.12 to its preceding neighbor, every third term the ratio $\sqrt[10]{10}$ or 1.26, and every fourth term the ratio $\sqrt[5]{10}$ or 1.58. Here we find a system of numbers in a simple, finely graduated geometric series capable of yield-

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ing, without any change in values, three other simple geometric series of increasing coarseness.

The system seems ideally suited to our requirements of flexibility in the selection of speeds. All terms are in geometric progression. Any one of the four series may be selected, depending on the requirements as to fineness of graduation. If over part of a range of speeds required by a certain variety of industrial equipment the coarser graduations are inadequate for certain specific applications, while suited to the range as a whole, terms from the next finer series may be injected where required without in any way interfering with the original series and still maintaining a geometric relation between all terms. For some applications, however, all required or desirable ratios cannot perhaps be taken from these four series as they may be either too fine in one case or too coarse in another, depending upon the selection made. The range of ratios may therefore be extended to include 2 and $\sqrt{2}$ or 1.41, and the six ratios, 1.06, 1.12, 1.26, 1.58, 1.41, and 2, should meet every requirement. Because of the mathematical relationship existing between the last pair of ratios and the other four, shown below in Table 1, the two new series produced result in no new terms, all being found in the original series "40."

TABLE 1 MATHEMATICAL RELATIONSHIP OF BASIC RATIOS

Series designation	Ratio — Based on $\sqrt[n]{10}$	Ratio — Based on $\sqrt[n]{2}$	Ratio — Numerical value	Resulting speed reduction, per cent: Accurate	Resulting speed reduction, per cent: Approximate
40	$\sqrt[40]{10}$	$\sqrt[12]{2}$	1.06	5.6	5
20	$\sqrt[20]{10}$	$\sqrt[6]{2}$	1.12	10.9	10
10	$\sqrt[10]{10}$	$\sqrt[3]{2}$	1.26	20.6	20
5	$\sqrt[5]{10}$	...	1.58	36.9	40
$\sqrt{2}$	....	$\sqrt{2}$	1.41	29.2	30
2	....	2	2.00	50.0	50

These series of preferred numbers, however, based on unity with the cycle recurring at 10, 100, 1000, etc., do not lend themselves to the speeds of electric motors, which are fundamentally fixed by the frequency of the current and which exert a wide-spread influence on the speeds of machine tools and other driven machinery. In order to accommodate this necessarily important factor in Germany, with 50-cycle current, the numerical values of the preferred-number series were shifted from the basic figure of 1 to 1.18, and in the United States the starting point, in order to cover the more important 60-cycle speeds, should be changed from 1 to 1.12. A-c-motor speeds are synchronous speeds, i.e., no-load speeds, while d-c-motor speeds are usually given as load speeds which approximately equal the nominal speed of a-c motors. The synchronous speed of the a-c motor is therefore the governing factor.

In the first six columns of Table 2, one cycle or decade each of the six series of preferred numbers, the "40," "20," "10," and "5" series and the two additions based on $\sqrt{2}$ and 2, which form the basis for the proposed series of standard speeds, are tabulated, and it might be well to mention here that the ratio 2 has been included mainly to accommodate the speed ratio 2:1 of multiple-speed motors. The displacement of the basis or starting figure of these series from 1 to 1.12 was made in order to accommodate the principal motor speeds in as many as possible of the six series of numbers established, and upon referring again to our preferred numbers, the first six columns of Table 2, we find that the major motor speeds occur in anywhere from one to all six of the series. The speeds of 450 and 1800, represented by 4.5 and 1.8, each occur in all six series, 900 and 3600 each occur five times, 112 and 720 each four times, 144 (140) three times, 514 (500) twice, and 300 and 1200 (1180) each once.

Wherever a theoretical law is applied in actual practice, deviations are bound to occur, and this is true of the preferred-number series when applied to the fixed speeds of motors. These discrepancies are of little consequence, however, when viewed in the light of the fact that the calculated or nominal speed is seldom, if ever, the load or operating speed of the machine. The speed at which a machine is designed to run is always known, but its actual speed is a function of any number of contributing factors among which may be mentioned the following:

a Size and type of motor
b Magnitude of load
c Efficiency of motor
d Kind of drive and its elements
e Condition of drive
f Number of transmission elements.

Any one or all of these items influence to some degree the magnitude of the speed drop from the synchronous values, and the actual speeds are therefore subject to variations in comparison with which the differences existing between the preferred numbers and certain of the synchronous speeds are insignificant indeed.

PROPOSED STANDARD SPEEDS

Now let us turn to the work of the Sectional Committee on Standardization of Speeds of Machinery. Almost entirely on the basis of speeds already existing in industry or considered desirable for application to future development, a list of proposed standard speeds has been compiled (see Table 2, columns 7 to 10, inclusive). They are intended primarily as speeds of driven machinery and therefore do not contemplate all 60-cycle a-c-motor speeds. They range from 22 to 54,000, a span sufficient to cover all industrial requirements for a long time to come. This proposed series, if established, however, will not in itself supply all the speeds or variations of speed required. In certain instances the interval between the terms will prove too small, while in others it will be too great and other intervening terms will have to be supplied. Our efforts, then, should not be just directed toward establishing certain necessary or desirable but otherwise isolated speeds. We must instead establish a system of speeds most certainly containing these necessary terms, yet capable of flexibility and expansion, with each term, whether in a contracted or expanded series, bearing to its neighbors a definite predetermined geometric relation.

How closely the Committee's proposal comes to meeting these requirements, all of which are embodied in the preferred-number series based on 1.12 rather than 1, may be taken as a measure of its ultimate worth.

Upon tabulating the speeds proposed by the Committee adjacent to the first decade of the adapted preferred-number system, as shown in Table 2, their agreement in general with the terms of the "10" series is immediately apparent. Deviations exist of course, all of which could with advantage be eliminated; in some cases by shifting up or down to the next synchronous speed, and in others by supplying additional terms as in the case of 2250, 4500, and 9000, which in the Committee's proposal were omitted. Other terms again such as 300, 600, and 1200 should, in the initial series, be replaced by speeds based on $\sqrt[10]{10}$, thus preserving a uniform ratio throughout. These three synchronous speeds thus eliminated

and other speeds which do not occur in the "10" series but which may be required can then be obtained by introducing selected terms from the "20" or "40" series or by adopting the "20" or "40" series as a whole for certain applications. It is interesting to note, however, that the speeds selected by the Committee fall, with reasonable accuracy, into the system of preferred speeds predetermined here as the rational solution to this problem in standardization.

In the last four columns of Table 2 a suggested revision of the Committee's proposal is tabulated, the discrepancies appearing in the original having been eliminated as suggested, thereby preserving the identity of the characteristic increment ratio of the "10" series, namely, 1.26. This revised series based on $\sqrt[10]{10}$ will not of course meet all the varied industrial needs as it stands. It is proposed, however, only as an initial or general-purpose series which, by virtue of the preferred-numbers relationship existing between its terms, is capable of orderly expansion to meet all requirements simply through the addition of the term selected as required from the other five series.

No one will question that many economic advantages are to be gained through the standardization of industrial speeds. The user of machine tools and other driven machinery will perhaps be benefited most. The machine-tool builder also will receive his share of advantage through the simplifying influence of standard speeds on such items as gear-box design and pulley diameters, in addition to the added advantage of competitive equality on the basis of speed. The international aspect, too, is worthy of some thought. With our speeds based upon the same fundamental series as those of Germany, France, and the remainder of Europe eventually, and differing from them only relatively by the shift of the starting point from 1.18 to 1.12, due to the existing difference in a-c frequency, American machines are readily adaptable to European needs or vice versa by simply building in a compensating gear.

Standard speeds will grow of themselves and become established as a result of necessity. Other standards—and many of them—have been allowed to grow in this self-same way, but always to plague the industries concerned in after years through the unwieldy and uneconomical array of terms or sizes resulting. The proper foundation is being laid in the present instance, and a rational series of standard speeds can therefore be established in industry to take the place of the present-day confusion. To realize this ambition, though, the serious efforts and conscientious support of industry as a whole must be accorded to the task.

TABLE 2 PROPOSED STANDARD SPEEDS FOR AMERICAN INDUSTRY

Adaption of preferred numbers to American speed standardization — Series designations						Proposed standard speeds recommended by Sectional Committee—Z18 — Rpm				Suggested revision of Committee's proposal — Rpm			
40	20	10	5	$\sqrt{2}$	2								
Increment ratios													
$\sqrt[40]{10}$ or 1.06	$\sqrt[20]{10}$ or 1.12	$\sqrt[10]{10}$ or 1.26	$\sqrt[5]{10}$ or 1.58	$\sqrt{2}$ or 1.41	2	11.2 to 105	112 to 1050	1120 to 10,500	11,200 to 105,000	11.2 to 105	112 to 1050	1120 to 10,500	11,200 to 105,000
1.12	1.12	1.12	1.12	...	..	..	112	...	...	..	112	1120	11,200
1.18	...	..	..	...	..	..	...	1200	...	..	...	..	...
1.25	1.25	..	..	1.25	..	..	...	...	12,600	..	...	..	...
1.32	...	..	..	...	..	..	...	...	...	..	...	..	...
1.40	1.40	1.40	..	...	..	..	138	...	14,400	..	140	1400	14,000
1.50	...	..	..	...	..	..	...	1500	...	..	...	..	...
1.60	1.60	..	..	...	..	..	164	...	...	..	...	..	...
1.70	...	..	..	...	..	..	...	...	...	..	...	..	...
1.80	1.80	1.80	1.80	1.80	1.80	..	...	1800	18,000	..	180	1800	18,000
1.90	...	..	..	...	..	..	...	...	...	..	...	..	...
2.00	2.00	..	..	...	..	..	200	...	...	..	...	..	...
2.10	...	..	..	...	..	..	...	...	21,600	..	...	..	...
2.25	2.25	2.25	..	...	..	22	...	...	...	22.5	225	2250	22,500
2.35	...	..	..	...	..	..	240	2400	...	..	...	..	...
2.50	2.50	..	..	2.50	..	..	...	...	25,200	..	...	..	...
2.65	...	..	..	...	..	..	...	...	...	..	...	..	...
2.80	2.80	2.80	2.80	...	..	28	...	...	...	28.0	280	2800	28,000
3.00	...	..	..	...	..	..	300	3000	...	..	...	..	...
3.20	3.20	..	..	...	..	..	...	...	32,400	..	...	..	...
3.40	...	..	..	...	..	..	...	...	...	..	...	..	...
3.60	3.60	3.60	..	3.60	3.60	36	360	3600	...	36.0	360	3600	36,000
3.80	...	..	..	...	..	..	...	...	...	..	...	..	...
4.00	4.00	..	..	...	..	..	...	...	39,600	..	...	..	...
4.25	...	..	..	...	..	..	...	...	...	..	...	..	...
4.50	4.50	4.50	4.50	...	..	45	450	...	...	45.0	450	4500	45,000
4.75	...	..	..	...	..	..	...	...	46,800	..	...	..	...
5.00	5.00	..	..	5.00	..	..	...	...	...	..	...	..	...
5.30	...	..	..	...	..	..	...	...	54,000	..	...	..	...
5.60	5.60	5.60	..	...	..	56	...	...	...	56.0	560	5600	56,000
6.00	...	..	..	...	..	..	600	6000	...	..	...	..	...
6.40	6.40	..	..	...	..	..	...	...	...	..	...	..	...
6.80	...	..	..	...	..	..	...	...	...	..	...	..	...
7.20	7.20	7.20	7.20	7.20	7.20	72	720	7200	...	72.0	720	7200	72,000
7.60	...	..	..	...	..	..	...	...	...	..	...	..	...
8.00	8.00	..	..	...	..	..	...	...	...	..	...	..	...
8.50	...	..	..	...	..	..	...	...	...	..	...	..	...
9.00	9.00	9.00	..	...	..	90	900	...	...	90.0	900	9000	90,000
9.50	...	..	..	...	..	..	...	...	...	..	...	..	...
10.00	10.00	..	..	10.00	..	..	...	...	...	..	...	..	...
10.50	...	..	..	...	..	..	...	10,800	...	..	...	..	...

CHARLES MacCAUGHEY SAMES, 1866–1933

CHARLES MacCAUGHEY SAMES, since 1916 associate editor of The American Society of Mechanical Engineers, New York, N. Y., died suddenly at his residence, the Hotel Robert Fulton, New York City, on March 8, 1933.

Mr. Sames was born on May 12, 1866, at Rockford, Ill. He was the son of Peter and Mary E. (MacCaughey) Sames. Matriculating at the Worcester Polytechnic Institute, Mr. Sames soon transferred to the newly formed Rose Polytechnic Institute at Terre Haute, Ind., from which he was graduated, in 1886, with the degree of Bachelor of Science.

Following graduation, Mr. Sames came east and entered the Thomson-Houston Electric Company, Lynn, Mass., where he worked as a draftsman and in the testing department under Professor Elihu Thomson. In 1887 he returned to his native town to enter business with his father, Peter Sames, who was a manufacturer of agricultural implements. He continued in the business until 1900 when he entered upon his editorial career.

CHARLES M. SAMES

During his manufacturing experience, at first as superintendent and from 1894 to 1900 as business manager, Mr. Sames was in responsible charge of all designing of jigs, fixtures, and special tools, and the repair and alteration of the buildings, power plant, and machinery. He also designed and built various special machines and labor-saving devices, such as gang boring machines, eye benders, and a line of small direct-current generators.

Mr. Sames's first venture in literary and editorial work was the compilation and editing of a "Pocket Book of Mechanical Engineering," published in 1905, and republished in its fourth edition in 1911. This "pocket book" included valuable data gleaned from publications in foreign languages and for that reason not available to the average engineer.

In 1906 he became editor of book publications of the Engineering News Publishing Company, New York. From 1907 to 1913 he acted as associate editor of *Technical Literature*, and its successors, *The Engineering Digest* and *Industrial Engineering* in which his experience as a designer, manufacturer, and editor of the "pocket book" provided him with an unusually valuable and comprehensive background.

Returning to the work of editing handbooks, Mr. Sames, from 1913 to 1916, assisted Professor Lionel S. Marks, of Harvard, in the preparation of Marks's "Mechanical Engineers' Handbook."

In July, 1916, Mr. Sames joined the staff of The American Society of Mechanical Engineers, as associate editor, a position which he held until his death. His talents were employed on the Society's "Journal," now known as "Mechanical Engineering," and on the editing of engineering and technical papers for the "Transactions" of the Society.

Bringing to this work a broad and comprehensive knowledge of the theory and practice of the profession of mechanical engineering and an extraordinary experience in the editing of engineering literature, Mr. Sames gave the publications of the Society a deserved reputation for high quality and accuracy.

It was Mr. Sames's rare combination of editorial skill, knowledge, and experience, and familiarity with the technical literature in foreign languages as well as in English, that made him especially competent to aid in the successful publication of The Engineering Index which the A.S.M.E. acquired in 1918. His meticulous editorship of engineering papers published in the Transactions and Mechanical Engineering transformed hundreds of indifferently written and amateurishly prepared manuscripts into accurate and creditable contributions to the literature of engineering. And with the coming of the *A.S.M.E. News*, in 1921, his talents were employed in the final scrutiny of its pages. On all of these publications he left the imprint of his literary craftsmanship, in the apt turning of a phrase, a remarkable clarity and conciseness of expression, a high degree of professional and editorial dignity, a meticulous accuracy, and a tastefulness in typographical arrangement.

On December 20, 1899, Mr. Sames married Lida Oliphant Falkinburgh, of Jersey City, who survives him. He is also survived by his brother, Judge Albert M. Sames, of Tucson, Ariz. He was a member of The American Society of Mechanical Engineers, of the Sons of the Revolution, New York, and of several clubs, including the Carteret and University Clubs of Jersey City, N. J. He was a protestant and a republican.

MECHANICAL ENGINEERING

Vol. 55 APRIL, 1933 No. 4

GEORGE A. STETSON, *Editor*

Charles MacCaughey Sames

FOR MANY YEARS every page of MECHANICAL ENGINEERING has borne the imprint of the editorial craftsmanship of Charles MacCaughey Sames, whose valued services were unexpectedly cut off in the midst of the preparation of the present issue. Elsewhere will be found a brief outline of the life of this unique figure in technical journalism. These few inadequate words are intended as a tribute to the nobility of character and the loyalty of service of one who strove to make this magazine as nearly perfect as it was in his power to do and who maintained for it traditions of worth, dignity, and accuracy.

The combination of his qualities was unique. The dignified urbanity of his manner cloaked a warm and gracious courtesy. A sparkling sense of humor brought an informal kindliness to his relationships with his colleagues, and with the thoroughness of his culture, based on natural inclinations and an educational and professional experience that wide reading and extensive travel in other lands had augmented, made him a true gentleman, keenly sensitive to human values. An inborn love for the fine arts was expressed at times in his life by playing the piano and painting in water colors. Working for the intellectual enjoyment of the task, he developed a superior craftsmanship, but did not, as others might have done, sacrifice quantity for quality; he was a rapid and an indefatigable worker.

Anticipating one day the time when the infirmities of old age might force his retirement from active life, he expressed to one of his colleagues the hope that some way might be found whereby he could edit an occasional paper, for he could imagine no happier way in which to end his days. His wish was answered, but not as he had anticipated, for he laid down his pencil one night and left his office in good health and with his usual vigor. Before it was time for him to return for the next day's work, without premonition, illness, or pain, he died.

Thousands of engineers are in his debt for the papers that through him were spread upon the record, and for the skill with which he prepared their generally inept writings for publication.

Earthquake Literature

THE DISASTER in California brings to mind the very practical contributions which the late John R. Freeman made to the means which men have of coordinating the work of engineers in construction to resist earthquake shock, the financing of insurance against such risks, and the scientific observations on the nature and occurrence of earthquakes made by seismologists, not only in his own professional work and his financial assistance to the work of others, but in his monumental book entitled "A Study of a Rational Basis for Earthquake Insurance," published shortly before his death.

A Stimulus to Thought

IN FEBRUARY and in March we published the papers presented last December at the yearly public meeting of the A.S.M.E. Special Research Committee on the Thermal Properties of Steam. Not to be confused with these more or less official documents—official in that their publication has the sanction of the committee—is a paper to be found elsewhere in this issue whose title is a query to which the author will appreciate a critical answer. Mr. Longwell has offered his paper "not necessarily as a contribution to learning, but as a stimulus to thought."

Economic Balance

IN JUNE, 1932, we published the first progress report of the American Engineering Council's Committee on the Relation of Consumption, Production, and Distribution. It attracted wide attention among readers of MECHANICAL ENGINEERING, many of whom wrote to inquire if anything beyond publication was to be the fate of so excellent a document. The Committee has been hard at work in the preparation of a second progress report, based on further study, and revised in the light of criticism and comment that resulted from the publication of the first. It is our privilege to present this second report to the readers of MECHANICAL ENGINEERING. Because of the length of the report, Part I only will be found in the April issue, it being the intention to publish Part II in May.

Part I of the present report analyzes 40 alleged causes of the business recession with respect to their effect on business stability, scale of living, and the distribution of goods.

Commendable as was the first report, the second is more convincing and more comprehensive. If the reader learns with disappointment that the committee can point to no single cause among the forty analyzed as being the sole factor to be dealt with, he can, at least, better appreciate the task that lies ahead, and find reason to be glad that the Committee did not, like so many individuals, run after a pet nostrum and blind its intelligence to a consideration of all others.

Much interest, because of the present banking emergency, will be found in the Committee's observations on financial causes. At the risk of emphasizing a detail in this connection, attention is directed to the following quotation in which the spirit of the Committee's approach to its task is displayed: "The operations of

banking are too vital to the maintenance of individual and general prosperity, too tempting in their profit possibilities to the inexperienced and to the dishonest, and partake so closely of the nature of a social trust, that they cannot be left open to free competition and initiative, nor are they completely so left in any civilized country."

Out of the Air

SNATCHED from the circumambient ether by the mechanisms which the genius of radio engineers has provided for even the lowly, unseen waves are transformed into audible sounds that make the entire world akin. While we have become quite blasé in our acceptance of such undreamed-of realities as hearing foreign statesmen addressing us on topics of the day, of vicarious attendance at concerts, dedications, and athletic contests, and of the admission to the privacy of our family circles of the world's entertainers, the events of the past few weeks have demonstrated once more in spectacular fashion the narrowing distances which separate men from places and events and the growth of mutual understanding that arises from hearing the other fellow's point of view.

For example, the pageant of the inauguration of President Roosevelt and the scenes and speeches with which it was accompanied were available to every citizen of the nation who could get within earshot of a loud speaker. And these events themselves were the culmination of a series of political events, begun in the national conventions, that made up the most unique presidential election the country has ever known in which the principal contestants spoke, not to an isolated audience of a few thousand, but to an entire nation.

There, too, are still fresh in mind the exciting days of early March when the Administration set itself resolutely to the task of dealing with the banking situation. An entire nation, regions of which with cruder methods of public announcement could have remained long in suspense, lacking the confident ring of the voices of leaders, heard from the President and from others whose opinions it had learned to respect on the reasons for the banking moratorium and the necessity for prompt calm action in an emergency.

More recently, with disaster crowding on the heels of economic misfortune, the scenes of the California earthquake were portrayed to the radio audience by trained observers, and the officers of the stricken communities were able to appeal to frightened friends and relatives of the inhabitants not to complicate an already difficult problem in emergency discipline by crowding into the devastated section.

These examples are familiar to every one as they concern our own national life and interests. But even more dramatic was the broadcasting to the press of the entire world from the League of Nations Assembly at Geneva of the 15,000-word Manchurian report. Probably the most noteworthy feature of this broadcast was its reception by the New York *Times* at its own radio station and its immediate transcription, with publication in full in the paper of the following morning. The acceptance by a great modern newspaper of the facilities of rapid news communication in such an important matter is most encouraging evidence of a spirit of progress that seizes upon the constructive possibilities of what some consider a competitor in its own field, and attack as such.

And finally there comes to mind a scene in the Assembly itself with the Chinese delegate offering, by means of radio, to let the other delegates listen to the firing on the Manchurian battlefields. With the possibility of so sensationally bringing the noises of armed conflict to the ears of the world, one can only speculate as to how powerful an instrument of peace such a device as radio might become were the horrors of war thus to be allowed to shatter the calm that pervades millions of hearthsides.

Road Hogs

EVERY ONE knows and berates the road hog. Having succeeded in getting at the head of the traffic procession he drives so that no one can pass him and on those who do he voices his displeasure. He assumes that his driving speed is the correct one. He does not intend to take the dust of those who might pass him, even if he is unable or unwilling to drive faster himself. He views his temporary leadership as an unquestionable right, and those who contest it as vicious upstarts who resort to unfair and dangerous competition.

Traffic on the highways of progress has always been retarded by road hogs. Industry has known many of them. They are the men and organizations that resist change, that fail to recognize the need for constant growth, that complain about competitors who have seized upon new methods, new materials, and new machines, that defy inevitable obsolescence and supersession, that call for restrictive laws and demand special privilege to make their own advantages secure against those that others develop for themselves.

Monopolies and special privilege breed complacency, indolence, indifference, and a false sense of security. For every industry, for every imagined monopoly, for every holder of special privilege, the germ of a menacing competition is in incubation if not already lustily alive. None can escape it; and only those who welcome decadence and soft living would attempt to do so, and these are likely to become road hogs.

The world has no sympathy for a road hog. When others pass him, and he chokes in their dust, few are sorry for him. There is no room at the head of a procession for the man who will not travel as fast as he can. And the industry that is not maintaining its rate of progress by ceaseless and diligent research and a study of its problems, cannot expect to stay in the lead. Road-hog tactics may delay others, but only unremitting energy and intelligence insure permanent advantage over a competitor.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

APPLIED MECHANICS (See Testing and Measurements: Integration and Pulsation Errors in Measurement of Quantities of Gas Flowing Through an Orifice)

Modern Developments in the Study of Turbulence

TURBULENCE plays an important part in all technically important processes of flow. It may be a cause of undesirable resistance to flow, but may also be very important and useful. It behooves any one studying processes of flow to master thoroughly the mechanics of turbulence, and a number of investigations have been recently undertaken with a view to establishing the laws of turbulent flow.

The present investigation by Dr. L. Prandtl is divided into two parts—one dealing with the origin of turbulence, and the other with the laws of turbulent flow coming into effect subsequent to the establishment of the turbulence itself.

Like all investigators, Prandtl starts with an expression for the Reynolds number involving the conception of kinematic viscosity—that is, viscosity divided by density. As to the causes of turbulence, he considers as the most important the law that turbulence can occur only when the velocity profile has a point of inflection, and provided the effects of viscosity are not too great. Where there is no frictional resistance, a flow with a viscosity profile such as that shown in an illustration in the original article is unstable, which means that small deviations in magnitude and direction of the velocity grow by themselves and ultimately cause a complete reversal of the flow. Because of this a wave in the line of flow which originally was very weak leads gradually by the superposition of waves to the creation of turbulence. This process can be, however, opposed or delayed by the action of viscosity. It would appear, therefore, that the tendency to the creation of turbulence is the greater, the greater the Reynolds number. Moreover there is another way of creating turbulence which has been discovered theoretically and which requires particular consideration where disturbances of the kind described above are not present. When flow takes place along a wall there occurs a peculiar kind of long wave disturbances above a predetermined critical Reynolds number. When their amplitude becomes sufficiently large they produce local causes for the creation of turbulence. It is more important to know, however, what happens once turbulence has been created, and it is to this subject that the major part of the present paper is devoted. Dr. Prandtl starts consideration of the subject by determining the behavior, with respect to turbulence, of an ideal liquid having no viscosity whatever. There is, of course, no such liquid actually in existence, but it is worth while to consider what may be expected to happen in such an ideal liquid, because the laws governing the turbulent behavior of the ideal liquid are simpler on account of the absence of viscosity than in the case of actual liquids. If we assume the limiting value of viscosity to be zero, the Reynolds coefficient becomes infinite, which would indicate that the flow of the ideal liquid must be generally turbulent. Should we further assume that the bodies or walls along which the flow takes place have a mathematically smooth surface we shall find that the surface friction (because there is no viscosity) is also equal to zero, which again gives us the classical behavior of the ideal liquid such as has been described in all the old hydrodynamics. If it be assumed, however, that the surfaces are rough, it will be necessary to assume a plane of partition, at each individual point of roughness no matter how fine the individual elements of roughness may be. Through the interaction of the various small planes of partition, which are unstable in themselves and out of regular order with respect to each other, the flow of liquid acquires a turbulent character. At each element of roughness there is then a difference in pressure between the front and the rear sides, which, in turn, creates a resistance proportional to the square of the viscosity.

The author claims that theoretically the laws of turbulence may be considered by assuming the viscosity of the liquid to be equal to zero. Moreover, this is further justified by the fact that in the interior of a flow the turbulent resistances practically do not depend on the viscosity. However, in the narrow zone in the proximity of the walls, one must consider the influence of viscosity as long as it is not superseded by the influence of a coarse roughness.

For a more precise investigation of turbulent processes of mixing, a conception has been usefully employed which the author designates as the "path of mixing," this concept playing in the case of such processes the same part as the average free length of path in the case of molecular diffusion in a gas. In both of these kinds of processes, shear stresses (or more correctly, apparent shear stresses) are created through the fact that there is a constant exchange of magnitudes of motion between the various layers of the liquid flowing side by side at different velocities. The author indicates next how a comparatively simple conception of these processes, which are actually quite involved, can be obtained. To do this it is assumed that a particle, which, because of collision with its neighbors, has acquired a velocity crosswise to that of the flow, has in the direction of flow on the average the magnitude of motion that belongs on the average to the layer in which the particle originated, and that the particle can move only through a distance l crosswise to the flow before it collides with other particles or mixes with them. Similar exchange motions go on in both directions, and the faster-moving layer takes up particles originating in the slower-moving layer, whereby, the motion of the faster layer is naturally retarded, while on the other hand, particles from the faster layer pass into the slower layer, causing an acceleration of the latter. The effect of the two layers of a fluid upon each other is therefore the same as if friction were present between them. The difference between the molecular processes and the turbulent processes is that in one case single molecules, and in the other case, whole masses of fluid, act as carriers in the exchange of energies. If u is the velocity of flow and y the coordinate in the direction crosswise to the flow in which changes in velocity take place, then the difference in velocities of two layers lying at a distance l from each other is in the first approximation equal to $l du/dy$. This in accordance with the preceding explanation is also the difference in velocities of a particle

which, coming from another layer, mixes with its new ambient matter. To determine, however, the force of friction, or, speaking more precisely, the shearing stress between the two layers, we must know how much of the mass is exchanged per second. The author derives an equation for the shearing stress, as follows:

$$\tau = \frac{1}{3}\rho\, cl\frac{du}{dy} = \eta\frac{du}{dy} \qquad [1]$$

where ρ is the density, c equals $3v'$, v' being the velocity of exchange between two layers. Where a turbulent exchange of mass takes place, it is permissible to assume that the velocity v' is of the same order of magnitude as the difference in velocities of two layers located from each other at a distance l'; the reason for this is that the globular masses of the fluid collide with each other at a velocity of that magnitude. By therefore suppressing the unknown numerical factor v', the formula

$$\tau = \rho\left(l\frac{du}{dy}\right)^2 \qquad [2]$$

is obtained for the shear stress. The suppression of this numerical factor implies merely a somewhat different definition of l. From this it follows that, as is found in nature where we are dealing with the simple effect of viscosity, the shearing stresses are proportional to du/dy and where the exchange is of a turbulent character (that is, where the existing effect of viscosity is neglected) the shearing stresses are proportional to $(du/dy)^2$, which is in accordance with the fact that hydraulic resistances are proportional to the square of the velocities.

The remainder of the article presents the theory of turbulent processes as propounded by Professor Kármán; the flow along a rough wall and the flow in a pipe. Incidentally, flow in sharply curved channels and the influence of heat exchange and turbulence are discussed. (L. Prandtl, in a communication from the Kaiser Wilhelm Institute for Investigation of Flow in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 77, no. 5, Feb. 4, 1933, 10 figs., pp. 105–114, including bibliography, *tA*)

ELECTRICAL ENGINEERING (See Foundry: The Witton High-Frequency Electric Melting Furnace; Special Processes: Practical Methods of Heating Solids by Induction)

ENGINEERING MATERIALS

Effect of Size of Specimen on the Strength and Elastic Properties of Cast Iron

THE present standard test specimen for cast iron is the so-called arbitration bar, which is a round bar 1.20 in. in diameter by 21 in. long, poured vertically in dry sand. According to the A.S.T.M. standard A 124-29, the bar is tested by placing it on supports 18 in. apart and applying a load at the center.

The tests reported in the present publication are claimed to show conclusively that, molding conditions being equal, the deformation per unit stress in ordinary cast iron varies according to the size of the section in which the iron is poured. The difficulty of judging this variation from the results of a single test specimen is apparent. Moreover, in the absence of more conclusive data than have been published, we question the advisability of basing judgment on the results of tests of small specimens extracted from various parts of the casting.

The physical properties of a given section in a structure are not necessarily a summation of the properties of the various components forming the member. It would seem desirable, in determining the physical properties of cast iron in sections of varying size, to test, whenever possible, each section as a whole. Incidentally, the data given indicate that reasonably good mechanical properties can be secured in gray cast iron without the necessity of resorting to unusual compositions or excessively high temperatures.

From photoelastic studies of materials as well as actual tests, it is known that high concentration of stress in stressed materials occurs adjacent to any discontinuities such as holes, cracks, etc.

The concentration depends on the size and shape of the discontinuity, increasing with the size and sharpness of angle of any void. In other words, we find the concentration greater next to a larger hole than to a small one, and greater at the end of a crack (provided it lies in a suitable plane) than adjacent to a round hole.

In the case of gray cast iron, it would seem that the sharp angular discontinuities in the iron matrix caused by the presence of thin graphite flakes would cause extremely high stress concentration adjacent to the edges of those flakes lying at the proper angle of the line of stress. This stress concentration can easily result in overstress of the affected parts, which relieve themselves by permanent deformation or fracture.

On the basis of this theory, with increasing size of graphite flakes we should expect increasing stress concentration with a resultant greater permanent set at a given stress. Conversely, we should expect improved physical properties, under static loading, with decreasing size of graphite flakes or in any change of shape that would tend toward a more rounded form.

Figs. 9 and 10 in the original article show that the stress-strain curve approaches a straight line as the size of the graphite flakes decreases. In malleable iron the graphite occurs as small rounded (nodular) masses, and malleable iron appears to have a quite definite modulus of elasticity with no appreciable permanent set occurring below the elastic limit. (A. H. Diercker, Research Engr., in *The Ohio State University Engineering Experiment Station Bulletin* No. 72 (vol. 1, no. 4, pt. 3, Engineering Series), July, 1932, 16 pp., illustrated, *dp*)

The Character of Cast Iron

ONE of the outstanding characteristics of cast iron is undoubtedly that the ultimate breaking strength calculated according to conventional methods from transverse tests is far greater than the ultimate breaking strength obtained by direct tensile test. This added strength, far from proving an asset to cast iron, has surrounded it with an uncertainty, to its very real disadvantage. It is true that tensile and so-called "transverse" strength have been correlated empirically, but the uncertainty has not been dispelled. The uncertainty is increased because the transverse strength of apparently identical bars varies widely, and the tensile strength varies somewhat (though to a smaller extent than the transverse strength).

The opinion which is advanced here as a result of an examination of test results on cast iron extending over many years is that this uncertainty is due to the attempt to interpret

the physical properties of cast iron in terms of a mathematical theory which does not apply to it.

Under the theory proposed here the transverse stress distribution of an ordinary grade of cast iron can be approximately represented by the type diagram in Fig. 1.

The curved line *XG* to the base line *XL* is the stress-strain line of the material in tension. The line *GL* represents the ultimate breaking strength of the iron. The curved line *XE* to the base line *XK* is the stress-strain line of the iron in compression. These lines represent the elastic characteristics, and if stress-strain lines obtained by direct measurement (and in which the plastic has been separated from the elastic component) be examined, it will be found that the relative curvatures conform to those indicated by *XG* and *XE*. These lines will be easier to recognize if they are redrawn to the more usual scales adopted for stress-strain lines, and this can conveniently be accomplished by drawing base lines *XL* and *XK*, respectively, to the scale given, but plotting the ordinates *G'L'*, etc., to five or ten times the scale.

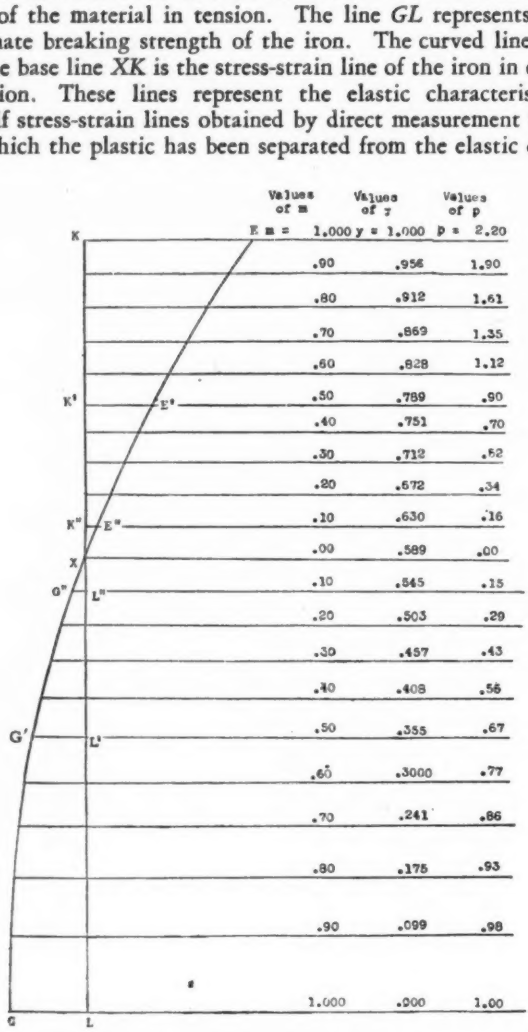


FIG. 1 APPROXIMATE REPRESENTATION OF THE TRANSVERSE-STRESS DISTRIBUTION OF AN ORDINARY-GRADE CAST IRON

In the case of the tensile-stress-strain curve the plasticity which cast iron possesses will increase the curvature to some small extent. On the compression side, however, plasticity will decrease the curvature of the elastic line. It appears from test results that the compression plasticity is sufficient to reverse the curvature of the compression elastic line.

The author claims that when a piece of material is stressed the resistance to fracture is purely an elastic reaction. Cast iron boasts both elasticity and plasticity in conjunction, but when, for example, the beam is loaded and then unloaded, only the elastic component of strain disappears, while the plastic component remains in the test piece. In order to correlate the breaking strength obtained from a direct tensile test with that obtained from the transverse test, it is necessary to distinguish between the plastic and the elastic components of strain, as the author shows from Fig. 1. Several comprehensive series of tests on bars as cast are quoted by the author. One of the deductions which he makes is that the character of the skin of cast iron is less constant than that of the inside. The skin has probably less plasticity than the metal inside in some cases and more in others, depending on slight differences in pouring conditions presumably difficult to control. These defects in the skin of the test pieces will exert a very serious influence at high stresses if the transverse-stress distribution is of the type shown in Fig. 1, although at lower stresses they will not be serious.

1 If all other conditions are equal, the moment of resistance of beams will vary as the square of their depth, so that if the skin is defective on the tension side to the same depth in each case a 1-in. × 2-in.-deep beam will show far less variations than a 1-in. × 1-in.-deep beam.

If the skin has less plasticity than the inside, there will be a tendency for the tensile and compression loads set up by the transverse loading to be concentrated in the skin, and for fracture to occur uncertainly owing to fortuitous defects in the skin.

2 If the skin on the compression face suffers appreciable plastic yield before the stress on the tension face has reached the ultimate value, the transverse-stress distribution will depart from that shown in Fig. 1. The compression-stress-strain line *XE* will be reversed in curvature, and the neutral axis *X* will tend to move toward the compression face. It is possible that the extreme-fiber tensile stress will not reach the ultimate breaking strength of the iron while this considerable plastic yield is being initiated on the compression side. The result would be to raise the apparent moment of resistance of the beam above that calculated from data assuming the transverse-stress distribution to be of the type shown in Fig. 1.

In brief, it is evident that plasticity on the compression face may increase the transverse strength appreciably. It is observable that this phenomenon is particularly in evidence on round bars of small diameter.

3 The number of flaws recorded in the tests raises a question whether the results are representative of foundry practice today. Further research with a view to the reduction of, or the elimination of, flaws is desirable. (*Mechanical World*, vol. 92, no. 2400, Dec. 30, 1932, pp. 621–622, 2 figs., *e*)

FOUNDRY

The Witton High-Frequency Electric Melting Furnace

THE Witton furnace, invented by Victor Stobie, is of the partially cored type. That portion of the magnetic field which does not pass through the charge, passes through thin laminations of special alloy steel having a conductivity for magnetic flux several thousand times that of the air path in furnaces of the coreless type. This alloy-steel path is brought to the nucleus of a core in a central position below the crucible and in line with the vertical axis of the inductor coil. The electromagnetic system furnishes an intensely strong and centrally situated magnetic field within the crucible containing the charge, and results in obvious and valuable economies.

It will be evident that the provision of this ferromagnetic path or partial coring has the additional effect of reducing the

stray magnetic field to an imperceptible amount and has an important influence on the general construction of the furnace. The furnace body is of substantial iron and steel construction which will withstand the rough usage of the workshop, while the massive alloy-steel container forms a rigid support for the internal crucible and the inductor coil and for the external body. Since mention has already been made of the use in some coreless furnaces of sheet-copper shields in an attempt to prevent overheating of the furnace casing by stray fields, it should perhaps be pointed out here that, since such a field cannot terminate in a core entering the vertical axis of the inductor coil or furnace, the presence of the stray field must tend toward decreased efficiency.

The furnace and the diagram of connections are described and illustrated in the original article.

The surface of a bath of molten metal in a high-frequency induction furnace is convex, the level of the center part of the surface being higher than that of the sides. This is due mainly to the known phenomenon of interrepulsion between adjacent conductors carrying electrical current in opposite directions. The current in the furnace charge travels in the opposite direction to the current in the inductor. Actually, the interrepulsion is between the opposed magnetic fields of the two currents. It has already been shown that the electromagnetic system of the particular furnace under discussion insures an intensely powerful flux which, being centrally placed, repels in a radical outward direction the field of the current it induces in the charge, and tends to push the molten metal up the inner wall of the crucible. By the nature of the total forces, the central axial rise of the metal remains the stronger, but the circumferentially upward force opposes any abnormal central "swell" of the charge. But for this fact, the relatively low periodicity of current which is used on the Witton furnace would cause a greater swell on the surface of the bath than is desirable for metallurgical reasons. Another factor which reduces this "swell" in the partially cored furnace is that the design facilitates the use of a reasonably wide crucible. Narrow and deep crucibles tend to increase swell. It will, of course, be apparent that the automatic stirring effect which causes this "swell" is a most desirable feature, as each melt is of uniform composition throughout.

The furnace enables steel to be used on a commercial scale and under ordinary workshop conditions with a precision which otherwise is obtainable only in the laboratory. This applies, of course, to other types of induction furnaces as well.

A further feature which is of the greatest metallurgical importance, and which is peculiar to the high-frequency electric melting furnace, is the automatic stirring action which is caused by electrodynamic forces within the molten charge. This insures a uniformity of composition throughout each charge which is not possible in any other type of furnace. An alloy, such as high-speed steel, the constituent materials of which vary considerably in specific gravity, is melted under conditions which do not permit of any variation in composition from top to bottom of an ingot, nor between any two ingots from the same charge.

As regards the economic side, it is stated that the current consumption of the Witton high-frequency furnace is lower than that of an arc-type furnace, and it is claimed to be lower than that of other high-frequency furnaces. It is stated, for example, that a run of nickel-chromium-molybdenum stainless steel was done with a current consumption of 574 units per ton. Maintenance costs are said to be low. (Verdon O. Cutts in *Foundry Trade Journal*, vol. 47, no. 851, Dec 8, 1932, pp. 354–357, 358–360, *d*)

FUELS AND FIRING

The Use of Low-Volatile Duff for Pulverized-Fuel Firing

By DUFF is meant the fine-sized coal which forms a part of the colliery output, the installation here described consisting initially of a Babcock & Wilcox boiler with a normal rating for evaporation of 40,000 lb per hr. The stoker firing equipment was completely removed and the boiler raised about 20 ft. The furnace was rebuilt with air-cooled refractory walls of Detrick construction, and fitted with two 10-in. Lodi burners in the front wall. A Fuller-Bonnot mill was installed for pulverizing, and arrangements made to feed this mill with hot air from the boiler furnace. With the Lodi burner the secondary air is under pressure, which is said to insure effective turbulence and enable much closer flame control to be achieved. The flame from the burner is short, so that impingement on the walls or boiler tubes is avoided. The air in the furnace walls is under pressure, and in operation it has been found possible to work the boiler normally at 50,000 to 60,000 lb evaporation per hr, and 63,000 lb has been recorded without slagging troubles and a very small amount of excess air.

Since it is impossible to consume efficiently non-caking coal of duff size in an ordinary stoker grate, burning in the pulverized state is the economic solution. Detals of approximate analyses of coal and evaporation tests are given. The original article also gives a sectional view of the Lodi burner. From this it would appear that the secondary-air-supply outlet which encircles the primary-supply outlet terminates in a refractory sharp-edged orifice which causes a high degree of turbulence at the "vena contracta," approximately 1 to 2 diameters past the orifice. It is at this "vena contracta" or zone of restoration that the primary air and coal mix with the secondary air, the primary air stream having been previously split up into a number of streams by means of the adjustable deflector central with the primary air and coal inlet. (*The Steam Engineer*, vol. 11, no. 5, Feb., 1933, pp. 209–212, 6 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING (See also Measuring Apparatus: A High-Speed Indicator for Internal-Combustion Engines)

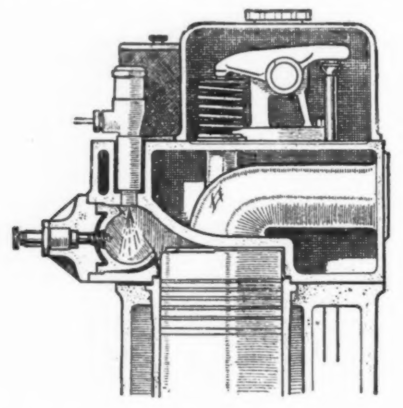
The Tangye Oil Engine

THE main feature of this engine when used for road vehicles is the Omo patent combustion chamber. This comprises a hot body or bowl and a transfer passage of peculiar form, the combination producing a condition of controlled turbulence on the compression stroke. The air above the piston is able to pass through a passage of large area into the hot body; this condition holds until the piston approaches the top of its compression stroke, when the area of the passage is reduced by the piston itself, and at this stage high velocity and turbulence are created. It is said to have been demonstrated photographically that practically all the first part of the combustion takes place either in the hot body or the transfer port, and not over the piston. As the flame propagates and the piston descends, free action is given to the expanding gas.

An important feature is that the air, in entering the hot body, is divided into two streams, and it takes up heat from the mass of insulated metal. As injection begins, the velocity of the air is maintained, the compressed-air streams cutting the oil spray at right angles.

Another important point is the raising of the temperature of the hot body and its maintenance at the correct temperature.

The body itself is made of a heat-resisting alloy called Nicrosilal, and its weight is 15 oz. It is surrounded by a small air space, being held in a screw cover of aluminum alloy, with which it makes contact through only a moderate area. The screw cover has vanes to dissipate excess heat, and although the hot body takes up heat rapidly when the engine is started, yet it does not rise in temperature above a dull-red heat, even with prolonged running. In short, it rapidly adjusts itself to the varying conditions of load, and it is clearly seen that the necessity of heating up a large water-cooled area before combustion can take place is obviated.



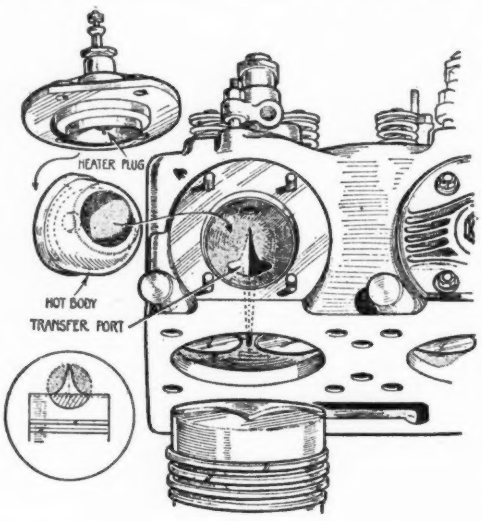


FIG. 2 OMO COMBUSTION CHAMBER IN THE TANGYE OIL ENGINE

The engine is normally run on light oils, but is capable of operating on heavy fuels, and it is said that on fuels up to 0.92 specific gravity there is an improvement in the power and smoothness of running.

Fig. 2 shows the Omo combustion chamber. The drawing on the left shows the hot body and injector, but not the shape of the transfer port, this being shown on the right. The diagram within the small circle near the center shows how the piston reduces the port area when approaching top center. (*The Commercial Motor*, vol. 56, no. 1455, Feb. 3, 1933, pp. 856–858, illustrated, *d*)

The Leyland Oil Engine

THE original article gives some data as to tests of a Leyland oil engine on a commercial vehicle, with curves showing acceleration of a fully loaded chassis and braking performance. The combustion chamber is of the direct-injection type and is formed as a simple cup in the top of the piston. The piston cavity is slightly to one side and the fuel is injected obliquely toward the piston center, being kept well ahead from the cylinder walls where it might detrimentally affect the piston-ring lubrication. To insure a sufficiently rapid air swirl the inlet valves are screened on one side, thus directing the air stream. For this reason the valves are keyed in their guides, and to remove them the keys and their clips must first be removed. It is important that the valves should be correctly timed, as otherwise they might be struck by the pistons.

Fuel-injection changes range in period from about 5 deg of crankshaft rotation at no load to 25 deg at full load. General data of the tests are given in the original article. (*The Commercial Motor*, vol. 56, no. 1452, Jan. 13, 1933, pp. 764–767, *d*)

LUBRICATION

Hot Brass Pressings

THE present paper deals with the practice of J. W. Singer & Sons, Ltd., Frome, Somerset, England. It is said that accuracy of the pressings can be kept within a few thousandths of an inch, the fineness depending on and varying with the shape and size.

Plain and straight-cored work is an every-day matter, while designs that are undercut can be, within reason, successfully produced by using specially designed dies. Tailpipes and right-angled and obtuse bends can be produced with clean cores and sound walls of even thickness. Hitherto these were always difficult and expensive foundry processes, causing much waste without giving reliable results under hydraulic pressure. Pressings show none of the defects due to sagging cores, nor the porosity often found in this kind of casting.

The operation of hot pressing is a combination of two operations, namely, forming shapes with dies, and at the same time extruding the metal. This permits in the machining of pressed parts the use of multiple-operation fixtures, jigs, and repetition machining devices, quick-gripping collets, compressed-air chucks, etc., made possible by the fact that pressings have clean, smooth surfaces and skin, the same volume of outline, and are free from blowholes, cavities, and cracks. Data as to the plant equipment necessary are given in a very brief form.

Two different types of presses are said to be required: namely, the friction-driven or screw-type press, and the positive or crank-driven type. The friction- or screw-driven press is not so subject to peak-load effect as the positive type. The frame is of cast steel and stands vertically, carrying the friction driving arrangement overhead.

Vertically revolving friction disks operate each side of a heavy horizontal friction wheel fixed on the top of the screw. The nut for the screw is in the main frame, so the pressure is taken directly by the whole frame. By depression of the hand lever, the operator is able to slide the revolving side disk into contact with the friction wheel on the screw. The screw is rotated and, passing through the nut which is secured to the frame, takes a downward course, carrying the tool slide with it. The slide moves in long guides of a sliding fit and imparts a steady but sharply defined pressure, returning to the top of the stroke automatically. One half of the die is held in the slide and the other half fixed in a bolster secured to the bed. Up to 350 pressings per hour can be made on this type of press.

The positive or crank-driven press is constructed in a vertical cast-steel frame, the drive being obtained through a belt-driven flywheel in the lighter type and a geared drive in the heavy types. The foot pedal, when depressed by the operator, brings a sliding clutch into position in positive contact with the flywheel and, being keyed to the crankshaft, causes the eccentric or crankshaft to make one complete cycle. A connecting rod is directly coupled from the crank to the press block through the medium of a ball joint. The depression of the foot pedal thus makes the die block descend for the full length of the stroke equal to the throw of the crank. Fine

adjustment of the position of the blow can be made by means of a fine screw thread in between the crankshaft and the die block. A powerful brake automatically operates at the completion of each stroke and brings the crankshaft to rest at the top of the stroke. Owing to the manipulations necessary, such as feeding in of the billets and their removal, and lubrication of the dies, it is impossible to utilize the maximum number of strokes of which these machines are capable.

The crankshaft form of drive makes the force of the blow or squeeze definite. Care must therefore be exercised not to overload or obstruct the completion of the cycle of the crank, as otherwise great damage may result. For articles requiring a uniform pressure over their whole area and for pressings involving pin work and extrusion, these presses are an advantage.

The matters of die design, the life of dies, their utility, and means of economic production are discussed. It is stated that approximately 2000 heavy pieces and 10,000 light pieces may suffice to cover the cost of dies.

Until recently it was considered impossible to make work which was undercut in design or smaller in the middle section than at the top and bottom sections, owing to the inability of withdrawing the pressing from the solid die. The use of the split die has overcome most of these difficulties, and by this method work with outside screw threads can be made. The die is split in two halves, tapered off at the outside, and when put together to form a whole is positioned by dowel pins. It fits into a bolster which is bored taper so that the more the die is forced into it, the closer together the two halves of the die come. Provision is made for the lifting upward and outward of the dies from the pressing. As a result of this scheme, processes which were looked upon as difficult foundry jobs requiring special two- or three-part casting boxes can be successfully dealt with as pressings.

Among the metals used for pressings the following are listed: Forging-quality brass: 58 to 60 per cent copper, up to 2 per cent lead, remainder zinc; 23 to 28 tons tensile strength; 25 to 30 per cent elongation. It is pliable, will take intricate shapes, and give clear, definite outlines and details.

Manganese bronze: 58 per cent copper, up to 1 per cent lead, 1 per cent manganese, 0.1 per cent iron; tensile strength, 30 to 35 tons per sq in., and elongation, 24 to 30 per cent. It is particularly suitable for valves, pump rods, keys, and heavy bolts.

Naval brass: 61 per cent copper, 1 per cent tin, remainder zinc; total impurities not to exceed 0.75 per cent; tensile strength, 22 to 26 tons per sq in., and elongation, 20 to 25 per cent. The metal resists the corrosion of sea water.

High-conductivity copper: tensile strength, 14 tons per sq in., with 40 per cent elongation. This metal toughens considerably when pressed.

Of the other materials, particular reference is made to aluminum bronze, and to aluminum-zinc and aluminum-silicon alloys. The heat treatment of the latter two requires to be pyrometrically controlled. (J. W. Beard in *The Metal Industry* (London), vol. 41, no. 24 and 25, Dec. 9 and 16, 1932, pp. 563–564 and 591–592 and 597, 1 fig., *d*)

MACHINE-SHOP PRACTICE

Torch Hardening of Gear Teeth

THIS process is used for the localized heat treatment of gear teeth without subjecting the gear to the distortion caused by a liquid quench from a high temperature. It has been developed at the Westinghouse Nuttall gear plant, and is known to the trade as the Nuttall E P heat-treating process. It is claimed that the gear can be finish-machined to size and then heat treated by this process with absolutely no distortion of the gear proper and with no distortion (or a negligible amount) of the gear teeth.

The process requires trained and skilled heat treaters familiar with the characteristics of the oxyacetylene torch and capable of recognizing temperature by means of heat colors. The hardening is effected by playing the cone of a properly regulated torch flame on the surface or bearing face of each gear tooth. By means of a specially designed fork-type double torch two flames can be heating the surfaces on both sides of each tooth simultaneously. The details are given in the original article.

By this method of heat treatment only the working faces of the tooth are heat treated, while the rest of the gear remains in its natural condition. The working faces are hardened to 450 to 500 Brinell, while the core retains the high ductility of the original material. After hardening, if size will permit, the gears are given a strain-relieving draw in an oil bath. The process can be applied to articles other than gears, and surface hardening of plain carbon steels to 400 to 500 Brinell, carbon-vanadium steels to 450 to 550 Brinell, and alloy steels up to 600 Brinell, can be accomplished. The depth of hardening is approximately $^1/_2$ in., from a surface hardness of 500 to a depth hardness of 300 Brinell. (Norman E. Woldman, Metallurgical Engr., Westinghouse Elec. & Mfg. Co., in *Machinery*, New York, vol. 39, no. 6, Feb., 1933, pp. 379–382, illustrated, *d*)

MARINE ENGINEERING

Howden-Johnson Heat-Recovery System—A Funnelless Steamship

IN THIS system an attempt is being made to recover a substantial proportion of the 12 per cent of heat lost even where a good air preheater is used. The further attempt is

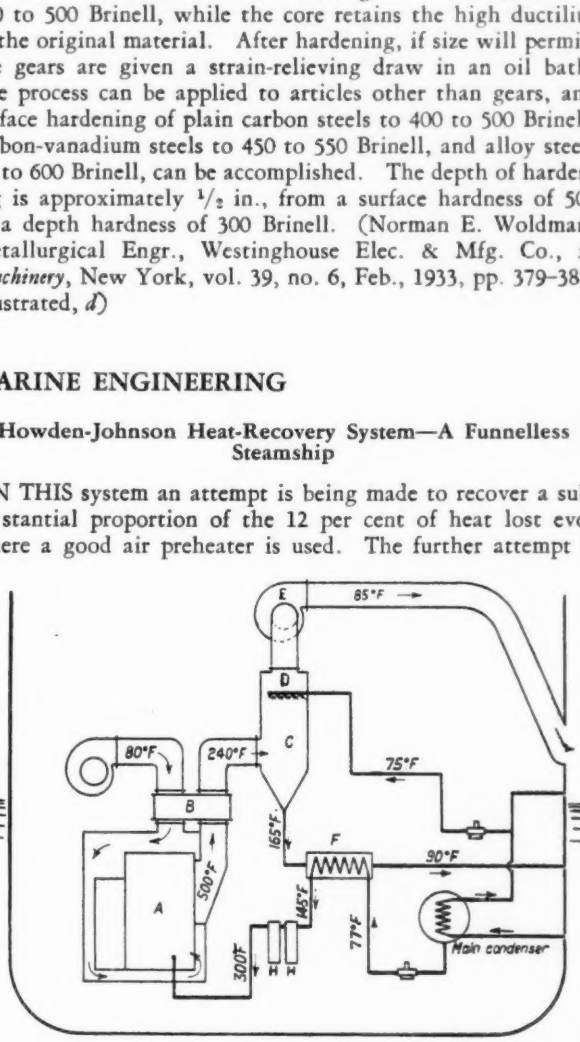


FIG. 3 DIAGRAMMATIC ARRANGEMENT OF THE HOWDEN-JOHNSON SYSTEM

to recover not only the sensible heat but also the latent heat of the moisture in the waste gases. As shown in the diagrammatic arrangement in Fig. 3, means are provided for washing the gases and extracting their heat by means of the washing water. The clean, cool gases can be then discharged through the side of the ship, making it unnecessary to retain the ship's

funnel. This method of utilization of the waste heat is said to bring the boiler efficiency into the region of 95 per cent, and in service a maintained efficiency considerably in excess of 90 per cent is expected. This affects not only the fuel consumption but also the weight and bulk of bunkers and machinery, with correspondingly increased cargo capacity. Moreover, the apparatus involved is of the simplest type, and the total cost of the complete ship incorporating the Howden-Johnson system will probably be less than that of the present conventional vessel.

The gases leave the boiler *A* at a temperature of 500–550 F and pass through an air preheater *B*, which reduces the temperature to 240 F. Thence they pass into a gas-washing chamber *C*, where they meet a supply of water from the main condenser discharge, which cleans them and reduces their temperature to about 85 F. The gases then enter the vortex chamber *D*, where any water which they are carrying is separated, and the dry, cooled gases are finally discharged by the induced-draft fan *E*, through a duct leading overboard.

The heat recovered from the gases in the preheater is taken up in the usual way by the air for combustion, which is raised in temperature to about 400 F, and the heat absorbed by the water in the chambers *C* and *D* is transferred in a heat exchanger *F* to condensate before it enters the interstage feedheaters *H*. In the heat exchanger the condensate is raised in temperature to about 145 F, and the water from the gas washer is cooled to about 90 F before being finally discharged under water. The temperatures mentioned above are on the assumption that the air temperature at the forced-draft fan is 80 F and the sea temperature 60 F.

As may be inferred, the system is applicable to any type of steam machinery working in association with either water-tube or cylindrical boilers, coal- or oil-fired. The auxiliaries, consisting of the air preheater, the gas washer and vortex drier, the heat exchanger, and the fans, are well-known, proved units, and they have all been used at sea in various applications, with the possible exception of the gas washer. The last-named appliance, however, is extensively used on land in spite of the difficulty frequently experienced there in providing an adequate supply of water. At sea, on the other hand, the water supply is unlimited, and the use of the washer is correspondingly simplified.

The original article also describes the Howden-Johnson improved Scotch boiler. (*The Shipbuilder and Marine Engine Builder*, vol. 40, no. 273, Jan., 1933, pp. 37–38, 2 figs., *d*)

The White Valve Gear

THIS gear is intended for marine high-speed reversible engines. The single eccentric driven by the crankshaft through a sliding block causes the valve rod to operate with a direct vertical motion. The eccentric rod acts as an inclined plane, and it is this special feature which reduces loads on vital points to a minimum and obviates heavy thrusts being imparted to the weigh shaft. The reversal is effected by a point at the end of the eccentric rod tracing out the arc. (This is used in the Marshall and Hackworth gears.) The cams are made to allow each valve to be adjusted independently, and the period of full opening is of longer duration per revolution than with slide valves and the opening and closing are quicker. This reduces the tendency to wiredrawing.

As the amount of water an engine will pass in unit time is a measure of its power, it follows that a poppet-valve engine, working under the same conditions as a slide-valve engine, can operate at a shorter cut-off, due to the smaller tendency to wiredraw, with a resulting gain in efficiency. Realizing the importance of this feature, and also the necessity for linking up one or another of the cylinders to obtain a balance of power throughout the engine, provision has been made to vary the mean area of the port opening in any one cylinder by making the cam operate its valve in a manner which will give it a displacement curve approaching that of a slide valve; or the reverse procedure may be followed. This condition is under the control of the attendant.

This type of valve, it is claimed, is suitable for engines requiring small receiver volumes and small pressure drops between the cylinders. When engines have cranks placed at 180 deg, this is particularly the case. (*Shipbuilder and Marine Engine Builder*, vol. 40, no. 273, Jan., 1933, pp. 45–46, 5 figs., *d*)

MEASURING APPARATUS

A High-Speed Indicator for Internal-Combustion Engines

THE author claims that a high-speed internal-combustion-engine indicator must fulfil the following two conditions in order that it may accurately indicate the pressure: (1) The connection to the cylinder must be direct; (2) the natural frequency of the moving part of the indicator must be high enough to permit the pressure of the piston or the diaphragm being indicated accurately.

The author criticizes the methods used in the previous electrical indicators and thinks that it is much simpler to move the mirror directly by means of the diaphragm rather than provide complicated contrivances only to cause the mirror of the oscillograph to turn through a certain angle. Mirrors are moved directly by means of the piston or diaphragm in ordinary optical indicators, but as their motions are relatively large, the natural frequencies are not very high. The natural frequency can be made sufficiently high by diminishing the motion and compensating the decrease of sensitivity by lengthening the arm of the optical lever. However, this principle has not been applied to ordinary optical indicators on account of engine vibration. But if the effect of engine vibration could be eliminated by some special device, accurate measurements could be obtained by increasing the natural frequency of the moving part and compensating the resulting lack of sensitivity by lengthening the optical lever. This is what the present indicator is actually doing. The natural frequency is from 7000 to 10,000 cycles per second. All moving parts were designed so that all their motions shall be elastic deformations. While the indicator is connected directly to the engine cylinder, a special device prevents the engine vibration from affecting the pressure indicator. (Fujio Nakanishi, Masaharu Iro, and Kikuo Kitamura in *Report of the Aeronautical Research Institute, Tokyo Imperial University*, vol. 6, no. 6, Report no. 87, Sept., 1932, pp. 161–177, 17 figs., *d*)

POWER-PLANT ENGINEERING

Steam-Pressure Transformers

IN ONE of its simplest forms the steam-pressure transformer consists of a steam-jet compressor in which a relatively small quantity of live steam is the agent by which a much larger amount of exhaust steam is raised in pressure and in temperature. Live steam is expanded in a divergent nozzle or group of nozzles, so that it issues at high velocity into a chamber to which the low-pressure steam is admitted. The latter is entrained and accelerated by the steam jets, and the resulting mixture enters the diffuser, in which its velocity

energy is converted into pressure energy, so that it can be delivered at a pressure intermediate between those of the live and the exhaust steam, as a rule being much nearer the latter. The action is, in fact, similar to that of the well-known steam-jet air extractor used in condensing plants.

The steam-pressure transformer may be regarded as a substitute for a reducing valve in many instances. Thermodynamically the jet compressor is a form of heat pump in which, by means of the energy supplied, heat may be taken in at a low temperature and delivered at a higher temperature.

The heat pump or thermo-compressor is not the only means by which steam can be made to evaporate more than its own weight of water. In multiple-effect evaporators this end is achieved by utilizing the vapor from the first steam-heated evaporating vessel or "effect" as the heating steam in a second effect. The final temperature is governed by the available cooling-water conditions, the final effect working at a vacuum and the vapor from it being condensed in order to maintain the vacuum.

In the evaporator provided with the thermo-compressor, the entire evaporation can be carried out at the lowest temperature, and at the same time economy in steam supply can be attained to a degree comparable with that of the multiple-effect system.

A single-effect evaporator (without vapor compression) may evaporate about 0.9 lb of water per lb of steam, a double-effect about 1.7, triple about 2.5, quadruple about 3.2, and sextuple about 4.2 lb.

With the recompression evaporator, about 2.0 lb to 2.3 lb of water per lb of steam may be evaporated. This figure may indeed be raised to about 4 lb per lb of steam, but the cost of the apparatus would be high. In comparing the recompression and the multiple-effect evaporators, the plant cost as well as the thermal efficiency must be considered. A lower efficiency may be amply compensated by cheapness and simplicity of apparatus.

The heat pump may be in forms other than the jet apparatus described. As a rule, a piston compressor is ruled out on account of its bulk; turbo-compressors, however, have been used with success, either steam or electrically driven according to circumstances.

A distilling plant working with a turbo-compressor on this system evaporated 76 lb to 80 lb of water per kwhr measured at the motor driving the compressor. In the concentration of chemical liquors, higher temperatures may be necessary, and the consequent higher compression ratio increases the power consumption.

One method of dealing with the rise of temperature due to the higher boiling point as concentration proceeds is to use a multi-stage compressor in conjunction with a multi-stage evaporating plant, the vapor from the dilute-liquor stage (at lowest temperature) being led to the low-pressure stage of the compressor, and the vapor from other stages at higher temperatures and pressures being led to the correspondingly higher pressure stages of the compressor. In this way the vapor from the higher stages need only be compressed through a reduced range, and a saving of power is the result.

The author refers to the Koenemann process in which mechanical compression is replaced by chemical action and to a recompression evaporator with jet-type compressor installed at Modena as early as 1924. He says that a test made on one such evaporator showed an evaporation of 4360 lb of water per hr for a steam consumption of 1870 lb, that is, 2.33 lb of water per lb of steam. This plant was built in accordance with the patents of Professor Gensecke.

The Lurgi Co., of Frankfort, has developed the steam-jet compressor, or pressure transformer, under Gensecke's patents. In addition to its application to evaporating plants, including plants for liquor concentration and for crystallization, it is also used for drying, the preparation of milk powder, the refining of vegetable oils, and, as referred to at the beginning of this article, for obtaining medium-pressure steam for factory purposes. As examples of the last-named, there may be mentioned the delivery of steam at 57 lb per sq in., from live steam at 298 lb and exhaust at 15 lb; at 15 lb from 128 lb and 7 lb; at 28 lb or at 43 lb from 156 lb and 21 lb, respectively. (T. B. Morley in *The Steam Engineer*, vol. 11, no. 5, Feb., 1933, pp. 205–207, *d*)

Boilers and Heat Pumps

THIS is an editorial explaining the elementary principles of the heat pump for the purpose of obviating hopes of attaining unrealizable thermodynamic gain. A heat pump is merely a reversed heat engine, and is subject to the same laws and limitations as the latter. Much more heat has to flow through a heat engine than could be turned into work, even if the engine were ideally perfect. Conversely, if the cycle be reversed, using the engine as a power-driven pump, the heat that it will deliver at the higher temperature is more than would be required to drive it. Extra heat can be obtained in this way, but even with ideally perfect machinery, no advantage can be gained from it.

If we want to pump heat from the atmosphere into a furnace, no method could be more efficient than causing air to expand isothermally behind a piston, the temperature of the expanding air being maintained constant by heat flowing in from the atmosphere. The air would then be recompressed adiabatically to atmospheric pressure and delivered to the furnace. If this process is to be carried out on one pound of air, originally at 60 F, the air being expanded isothermally to one-tenth of an atmosphere before recompression, the power theoretically required will be the equivalent of 34.4 Btu. The air, however, after recompression will be at a temperature of about 550 F instead of 60 F, and will therefore carry into the furnace 116.5 Btu more than it would otherwise have done. Deducting the power required to work the heat pump, we should seem to be making a clear gain of about 82 Btu for every pound of air so treated. But what benefit can we get from this heat, always supposing that our final object is to obtain power? We have a pound of air at atmospheric pressure and at a temperature of 550 F. There is evidently work to be obtained from it by reason of its temperature. We could use the heat to raise steam and thus drive a steam engine, or we could merely reverse the process by which we obtained it, allowing the air to expand adiabatically down to atmospheric temperature and then recompressing it isothermally to atmospheric pressure. Whatever kind of engine we use to develop the power, we could obviously couple it up to our heat pump. If, then, there is any advantage in our extra heat, the engine will not only drive the pump, but will produce some power over and above that consumed in driving it. In such a case we should have perpetual motion, which is impossible. The same reasoning, of course, holds whatever temperature the air is raised to by the heat pump and whatever pressure it is delivered at. It is clear, therefore, that all suggestions that a greater net power can be obtained from a boiler plant by pumping heat from the atmosphere into the furnace are devoid of reason.

The editorial next proceeds to expose a fallacy to the effect that more heat could be got into a boiler than the fuel would produce if motors were so arranged that the flue gases were

discharged below atmospheric temperature. The fallacy is due to neglecting the fact that the cycle is to be completed. Although the supercooled gases do not themselves travel back to the compressor inlet, a corresponding quantity of fresh matter has to enter the system, so that it is legitimate to imagine a continuous circulation of the heat-carrying medium. Hence we have to take into account the effect of the rewarming of the cooled gases to the temperature of the air entering the compressor. The latter is no longer able to receive the working fluid at the lowest temperature of the cycle, but at a temperature considerably higher, and thus the work of compression is correspondingly increased. To discharge the flue gases at any temperature below that of the atmosphere is, of course, quite possible, but should be avoided for thermodynamic reasons. (Editorial in *The Engineer*, vol. 154, no. 4016, Dec. 30, 1932, p. 669, *t*)

Have Steam Costs Hit Bottom?

THE author believes that operating costs in the production of steam are perhaps fairly close to bed rock. Coal prices are low and coal quality has improved, the poorest grades being practically unmarketable, while the better qualities are finding a constantly widening market. Operating efficiencies are setting new records due to the increase in willingness of plant owners to install heat-recovery apparatus, with refinements in equipment, instruments, and controls. Never before has steam-plant equipment been available of such high quality at such low prices. The author therefore comes to the conclusion that steam costs are now at the lowest levels. (Carl Stripe, Asst. to Vice-Pres., the Davis Coal and Coke Co., New York, N. Y., in *Steam-Plant Engineering*, vol. 2, no. 1, Jan., 1933, pp. 16–17, *g*)

PRINTING

Electrodeposition in Printing

BRIEF reference is made to the method of nickel-facing printing plates, both flat and rotary. For flat plates the electroplating vat is constructed of wood lined inside with chemically pure lead match-bordered and fitted with hardwood capping. Heating is important, as the temperature of the electrolyte must be maintained at 75 F. It is said that a London newspaper company saves 300 casts per week by nickel facing its page stereos. Nickel-faced plates give approximately 1,000,000 copies, and take the ink well and give a clear impression.

Nickel facing is of great importance in color printing from halftones, electros, and stereos, as it insures the correct tone in the reds, the brilliancy of which is lost through chemical action by printing from copper surfaces.

The subject of the application of nickel facing to rotary printing has received great impetus, resulting from the growth of photography. Two methods are used, namely, one in which the cylinder is totally immersed in the solution, and one in which the cylinder is partially immersed. Improved methods of burnishing have been introduced in which a number of agate burnishers prevent the growth of nodules. The reciprocating burnishing gear is readily moved for the purpose of loading and unloading cylinders. Copper cylinders receive the deposit in a copper-sulphate solution.

In the partial-immersion type of apparatus the cylinder is immersed in the solution to a depth of approximately one-third of its periphery, but no fittings are allowed to enter the solution. The cylinder revolves in ball bearings and is supported on cast-iron legs positioned clear of the vat at each end. In the heavy fast-running presses such as are used in offset printing—for example, in the Pantone process—the tendency is to rely upon the final deposition of chromium with the proper binder to the base metal. (*The Electrical Review*, vol. 112, no. 2879, Jan. 27, 1933, p. 114, 2 figs., *d*)

SPECIAL PROCESSES

Practical Methods of Heating Solids by Induction

THE methods of heating solid metals depend on whether the product to be heated is magnetic or non-magnetic, and even in the case of a magnetic material it should be remembered that above a certain temperature magnetism is lost. The article briefly states the principles underlying the inductive heating of solids. The present inductive methods of heating which may be employed commercially fall broadly into three general classes, namely, those in which the heating is wholly by direct induction; those in which the material is placed in a muffle, and the muffle walls are being heated by induction; and combination methods in which part of the heating is by direct induction and the remainder by heat radiated to it from the walls of a specially contrived inductive muffle.

When use of the direct inductive method is contemplated, the availability of reasonably priced frequency-changing equipment first deserves attention. The tonnage to be handled in the heating of billets and tubes must be sufficient to justify the installation of a motor-driven generator to supply current at a frequency of not less than 500 to 1000 cycles per second, and in special cases as high as 5000 cycles. Current of normal frequency, 25 to 60 cycles, is not generally applicable where direct induction methods are used and the temperatures required exceed the temperature at which magnetism is lost.

The second consideration is technical, in that the resistivity and the least dimension of a transverse section of a solid susceptor, as a billet, must be such that the greater portion of the electromagnetic energy which flows into it becomes changed into heat.

Finally the susceptor must have a geometrical symmetry which will allow it to be placed easily within an inductor coil and in a manner to permit of a close and uniform physical coupling at all points along the greatest length of the susceptor. Billets of round or rectangular section, pipes, or large-diameter tubing meet these conditions, while the crankshaft of an automobile engine does not.

One of the advantages of the direct induction method of heating is its speed. A particular case is cited by the author where a 1-in.-diameter steel rod 4 in. long was made to absorb 60 kw and come from room temperature to a forging temperature in 2 to 3 sec, and might have been heated faster with more power at disposal. (First instalment of a serial article by Dr. E. F. Northrup, Vice-Pres., Ajax Electrothermic Corp., Trenton, N. J., in *The Iron Age*, vol. 131, no. 4, Jan. 26, 1933, p. 165 and advertising p. 14, 2 figs., *dp*)

TESTING AND MEASUREMENTS

Integration and Pulsation Errors in Measurement of Quantities of Gas Flowing Through an Orifice

ATTENTION was primarily attracted to the integration of irregular flow rates by the fluctuating nature of gas flows from many of the producing wells in the Singu Field during a period when casing-head pressures were influenced

by a fluctuating gas-collection-line pressure, which was dependent upon the balance between supply and fuel demand. Gas flows throughout the entire system were therefore variable. It was very evident that the simple integration of orifice-meter charts and the existing methods of application of the flow formula $Q = C\sqrt{(\text{H.P./G.T.})}$ cu ft did not satisfy the nature of these flows, and that considerable errors were incurred. The aggregation of all chart errors assumed large proportions and, despite careful field supervision of the gas system, it was impossible to arrive at any satisfactory balance between "gas supplied" and "gas distributed" to field consumers.

The author shows the nature and extent of errors incurred in integration by popular methods, and also explains the nature of the meter errors involved in measurement of pulsating flows; he evolves formulas for the calculation of the reduction of these errors.

The author starts by giving the usual formula for the quantity of gas passing in cubic feet per hour, which is, however, the equation of the rate of flow at any instant. He believes, therefore, that the values of this formula should be simultaneous values at any particular instant. Moreover, as the magnitudes involved are themselves variables independent of time, integration is only possible for any period during which these values are constant, and he rewrites the equation in a manner that makes clear that direct integration is only possible for a period during which the magnitudes involved are constant. He presents an interesting classification of types of flow of gas in practice, and shows that certain flows can be directly integrated while others cannot be accurately integrated without supplementary information being supplied by a fast clock meter. He suggests that under certain conditions a reasonably accurate method can be devised for the integration of small time-scale charts on which are described records of the types of flow which cannot be accurately integrated without supplementary information. He believes, however, that the elimination of vibration and pulsation errors can be achieved only by inserting between the orifice and the source of flow a reservoir of sufficient capacity to insure that for a negligible change in the differential across the measuring orifice (that is, for a negligible change in reservoir pressure) the change in the contents of the reservoir is greater than the difference between the rates of flow into and from the reservoir. As reciprocating gas compressors are the commoner source of pulsation in practice, the discussion refers purely to rapidly pulsating flows of the type produced by modern compressors.

The author next develops a formula for determining meter errors in the measurement of compressor discharge, and supplies certain tables which permit practical calculations with the use of the formula. This is followed by a discussion of the reduction of meter errors in measurement of compressor discharge by velocity pulsation.

Appendixes deal with the following subjects:

Determination of the degree of inaccuracy in measurement which is incurred by the substitution of the square root of the true mean of a variable for the mean square root of that variable in the integral equation of flow through an orifice, in cases where: (*a*) there is only one variable, and (*b*) the duration of each successive period of uniform rate of flow can be accurately determined from the flow chart.

Determination of the degree of inaccuracy in measurement which is incurred by substituting the square root of the arithmetical mean of successive maximum and minimum values of a variable for the mean square root of that variable in the integral equation of flow through an orifice, in cases where: (*a*) there is only one variable, and (*b*) the duration of each successive period of uniform flow cannot be determined from the flow chart (i.e., periods are of extremely short duration, relative to the time scale).

Determination of the degree of inaccuracy of measurement which is incurred by substituting the square roots of the true means for the mean square roots of two variables in the integral equation of flow through an orifice in cases where: (*a*) there are only two variables, and (*b*) the duration of each successive period of uniform flow can be accurately determined on the flow chart.

Determination of the possible degree of inaccuracy in measurement which is incurred by substituting the square roots of the true means for the mean square roots of two variables in the integral equation of flow through an orifice, in cases where: (*a*) there are only two variables, and (*b*) the duration of each successive period of uniform flow can be accurately determined from the flow chart.

Determination of the degree of inaccuracy which is incurred by the substitution of the square roots of the means of successive maximum and minimum values of two variables in the integral of flow through an orifice, in cases where: (*a*) there are only two variables, (*b*) the duration of each successive period of uniform rate of flow cannot be determined from the flow chart, due to the time scale being too small, and (*c*) the variables change sympathetically.

Determination of the degree of inaccuracy in measurement which is incurred by the substitution of the square roots of the means of successive maximum and minimum values of the two variables for the mean square roots of these variables, in the integral equation of flow through an orifice in cases where: (*a*) there are only two variables, (*b*) the duration of each successive period of uniform rate of flow cannot be determined from the flow chart, due to the time scale being too small, and (*c*) the variables change antipathetically. (D. Gilmour in *Journal of The Institution of Petroleum Technologists*, vol. 19, no. 111, Jan., 1933, pp. 25–68, illustrated, *pmA*)

TEXTILES

Creaseless Textiles

THE invention of such fabrics has just been announced in Manchester, England. The process involves the permeation of fabric with synthetic resin. It is considered to be of great importance. Research work on this problem has been carried on for fourteen years by the Research Department of Tootal, Broadhurst, Lee & Co., Ltd., of Glosopp, England.

The synthetic condensation product in solution is pressed into the cotton fiber or rayon filament and permeates it much like dye permeates cloth. It is later converted into elastic resin by heating. The process is the last operation to which the cloth is subjected, i.e., the material is given the anti-crease treatment after bleaching, dyeing, printing, and finishing. The process is not suitable for application to cellulose acetate yarn.

Cotton fabric is padded with a liquor consisting of 20 parts of 40 per cent formaldehyde, 10 parts of urea, 5 parts of boric acid, and 60 parts of water, maintained at ordinary temperature and then dried at 130 C for about half an hour. Under these conditions the urea and formaldehyde condense under the catalytic influence of the boric acid to form a resin within the cotton fibers. Afterward, loosely adhering resin is removed by a boiling-soap treatment. Alternately, cotton fabric is mercerized in the usual manner, and after washing out the alkali, but before drying, it is impregnated with a mixture of 100 parts of phenol, 100 parts of 40 per cent formaldehyde,

and 4 parts of potassium carbonate, which is boiled for 5 min and then rapidly cooled. The fabric is then stentered on a hot-air stentering machine in such a way that it is dried at a low temperature, being afterward heated for two minutes at 170 C and finally soaped.

A catalyst is generally required in the formation of formaldehyde synthetic resins, and this may be acidic or alkaline.

The process adds weight to the material and is claimed to increase the dry strength by 30 to 50 per cent and the wet strength sometimes as much as 100 per cent. This is particularly important for rayon fabrics because of their weak strength when wet. (*Plastics and Molded Products*, vol. 8, no. 11, Nov., 1932, pp. 417, 432–433, *dA*)

THERMODYNAMICS (See Power-Plant Engineering: Boilers and Heat Pumps)

WELDING

High Frequency for Arc Welding

EXPERIMENTS with induction generators operating at frequencies ranging from 500 to 9000 cycles per second have shown that currents of such relatively high frequencies have important advantages for use in metal arc welding and for other arc applications of heat.

There are no surges of more than 10 per cent above normal in either voltage or current when short-circuits are made and broken by wiping the welder's rod holder quickly across the edge of the grounding base. The voltage and current curves (Fig. 5 in the original article) show practically normal conditions immediately after the short-circuit is broken or made.

The machine which the author describes consists of a generator of the double-core type designed to operate at 3600 rpm to produce welding currents at a frequency of 900 cycles per second. The machine is said to have the simplicity and ruggedness of a squirrel-cage motor, although the length of the air gap is almost twice that usually employed in an induction motor. The relatively high speed enables direct connection to gasoline engines of similar speeds, resulting in portable sets, compact and light in weight, and this machine makes a practical welding generator with which metal arcs are easy to strike and hold, and good penetration is obtained. It is particularly good where new heavy-coated rods are used and in other work where reversed polarity of direct current is recommended. With a carbon torch this high-frequency current is also useful. The arc projects so well away from the carbons that it is almost as handy to the work as is a gas flame. In the case of the carbon arcs the no-load voltage used is the same as for metal arcs. The carbon arcs operate at from 45 to 50 volts, with correspondingly lower current per circuit. It should be noted that this generator is operated at low open-circuit voltage, and is comparable to d-c machines in this respect. Metal arcs are easy to strike and hold at from 65 to 70 volts. Arcs of smallest current values can be held successfully with open-circuit voltages below 100.

Among the features of this high-frequency generator that command attention are:

1 Multiple circuits for more than one generator; simple adjustment of circuits.

2 No transients that affect the welding operation.

3 Low open-circuit voltage.

4 Inherent regulation, no external reactance or resistance required.

5 High efficiency.

6 Self-excitation, or optional separate excitation from any d-c source.

7 Weight and cost low; less than one-half the usual d-c machine; comparable to 60-cycle transformer equipments.

8 Three-phase loading of power lines as compared to single-phase 60-cycle transformer sets.

9 Rugged construction of rotor; no windings; no commutator; no brush wear.

10 Optional direction of rotation.

(G. A. Johnstone, Great Lakes Electric Mfg. Co., Chicago, Ill., in *Electrical Engineering*, vol. 52, no. 1, Jan., 1933, pp. 14–16, 6 figs., *d*)

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer.

Dust in Industry

(*Continued from page 233*)

million particles per cubic foot of air, it was found that practically 100 per cent developed an established silicosis within 10 years from the time of beginning employment. Also, in this group the highest rate was found for cases diagnosed on physical examination as having active tuberculosis. Furthermore, a definite relation was established between length of service in the industry and the prevalence of tuberculosis.

In group B were included those workers other than hand pneumatic-tool operators who were also exposed to more than the average plant dustiness. Taking the group as a whole, the average dust concentration was nearly 45 million particles per cubic foot of air. This group showed the same reflection of a dust hazard as group A.

In group C, consisting of those occupational groups exposed to the average plant dustiness (about 20 million particles per cubic foot of air), silicosis developed much more slowly than in the groups just discussed, and there appeared to be very little excess in the rate for tuberculosis, with no tendency for an increase according to length of service. Analysis of occupational mortality over a period of 25 years, however, indicated that some of the occupations in this group may have been exposed to a real dust hazard.

Group D was made up of those occupations in which the dust exposure was less than that of the average plant dustiness. The average exposure for the group was less than 10 million particles per cubic foot of air. Although a certain amount of silicosis was found even in this group, there was no indication of serious results, even when the workers had been employed for many years.

It is clear from these data that there exists a high correlation between the dust counts and the effects of this dust exposure on the health of the granite workers. It is obvious, therefore, that the technique of dust analysis described in this paper constitutes a valuable index of the hazardousness of dust inhalation, and one from which the degree of hazard may be judged with practical certainty.

CORRESPONDENCE

READERS are asked to make the fullest use of this department of "Mechanical Engineering." Contributions particularly welcomed at all times are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

Management Essentials for Recovery

To the Editor:

Referring to the paper entitled "Management Essentials for Recovery," by Carle M. Bigelow, in the November, 1932, issue of Mechanical Engineering, quite the most admirable contribution which the author makes is an eight-point program which he characterizes as "the management procedure required to bring about a general recovery of sound business conditions."

I find myself in substantial agreement with the wisdom of attempting to carry out this program. The probability that for an indefinite period of time its objectives will fail of accomplishment does not detract from its value as a platform upon which all may stand who believe that greater social control of business is essential to prosperity.

My reason for taking a somewhat pessimistic view of ultimate success lies in the requisite of concerted action involved. We must not be deluded by multiplying evidences of cooperation within industries at the present time. At the risk of being characterized as a cynic, I am compelled to interpret much of this so-called cooperation as an illustration of the old saying, "The devil was sick, the devil a monk would be."

Before commenting on other points of Mr. Bigelow's paper, I want to take the liberty of suggesting to him that in any possible review of his program, he appraise the value of introducing some reference to budgetary procedure and control. Because of his familiarity with this important technique of management, I assume that its omission was deliberate. It is my belief that it would strengthen his program materially if he were to stress budgetary procedure and control to the extent warranted. He might even go a step farther and substitute some such phrase as this: "Subject all activities of the enterprise to constructive plans of budgetary procedure and control" for his point *f:* "Put aside for all times the 'volume complex.' " This point really involves an admonition rather than a practical step, and it would simply vanish from the picture through the adoption of sound budgeting.

Let me now discuss from a different angle the author's paper as a whole. The title, "Management Essentials for Recovery," postulates of necessity an influential relationship between the acts or omissions of management and a state of prosperity. It is evidently the author's belief that this relationship is intimate and powerful, for he states that we are "primarily concerned with the steps management must take to produce a recovery in economic balance and prosperity." He therefore dismisses in his first words "all reasons why, or responsibilities for, the disturbed economic conditions of the last three years."

In the opinion of many qualified students of the situation, we are approaching the danger of an ultimate breakdown of our political and social structures; new concepts of control that will avert this huge threat to civilization have not as yet been fashioned. Without in the least desiring to sound a pessimistic note, I nevertheless venture to express the opinion that not until these larger and today almost incomprehensible problems have yielded somewhat to broad and all-embracing plans for their solution, will it be possible to advance materially in the field of accomplishment which Mr. Bigelow has set for management.

It is my belief that if there is any weakness in Mr. Bigelow's paper, it consists of his assumption that "the outstanding characteristic of the present depression has been the maladjustment between production and consumption." Waiving the question whether this characteristic is an antecedent or concomitant condition, I desire to point out that in my judgment he would have stated his case better if he had employed the terms "productive capacity" and "effective demand" in place of the two words actually used.

There can be no denying the fact that our productive capacity is at the present time greatly in excess of the actual, or prospective, effective demand. Moreover, there is a wide difference between effective demand and potential consumption. From the practical point of view, the problem to be solved is to induce business executives to accept the implications of these facts and to impose upon themselves the proper restraint in the formulation of their operating plans.

To narrow down the wide margin between potential and effective demand obviously requires a great increase in purchasing power. Obviously, too, the price system under which we are now operating enters as a vital element; and so again we find ourselves confronted with economic rather than with management problems.

Mr. Bigelow's suggestions concerning the technique of distribution are in harmony with approved modern practice. I do not, however, follow him when he urges the need of an "entirely new viewpoint" with respect to general administrative policies. What he describes under this head seems to me to be on all fours with practices prevailing in the better-managed business enterprises whose affairs have long since been subjected to the application of sound techniques of direction and control, reinforced by budgetary procedure.

As far as Mr. Bigelow's attack upon methods and records is concerned, I must part company with him, for I find it impossible to accept his generalization. While unnecessary costs are undoubtedly occasioned by elaborate methods and unproductive records, the remedy lies in the direction of constructive revision rather than periodic reduction. If statistics are worth while, their continued production is necessary for comparative purposes. I am quite certain that they are at least as reliable in practice as is the "intuition of management," a quality which I have seen in action often enough to make me rather skeptical as to its value.

Taken as a whole, Mr. Bigelow's paper is a thoughtful and constructive contribution to the building up of a body of sound opinion respecting one of the really great problems confronting business today. I am sure he will feel amply repaid for his labor if what he has written out of his wide experience may

induce the business world to enlarge its vision with respect to its share in the responsibilities and opportunities that lie ahead.

HARRY ARTHUR HOPF.[1]

New York, N. Y.

TO THE EDITOR:

Both Mr. Bigelow's paper and Mr. Alford's paper on "Ten Years' Progress in Management" are fine efforts, but I want to add another item that should be included as a part of the ten years' progress report and as an essential for recovery. This is the subject of unemployment insurance.

In February, 1931, the Rochester Chamber of Commerce reported that fourteen companies in Rochester had adopted what was to become known as the "Rochester Unemployment Benefit Plan." These companies were prompted by the thought that if industry did not do something to relieve the problem of unemployment due to seasonal variations in business or to depressions, the Government would, and if the Government did, it might be on less constructive grounds than if industry attended to the obligation itself. In addition to this motive was the sincere thought that a plan properly worked out would furnish a strong incentive to stabilize conditions and reduce the need for such insurance. The plan is as follows:

All employees receiving less than $50 a week are included. The benefit will be 60 per cent of the weekly earnings of the employee with a maximum of $22.50 a week, and will be payable after two weeks of continuous unemployment. The length of weekly payments varies with the length of service:

Length of service, years...	1–1½	1½–2	2–3	3–4	4–5	5 and over
Benefit, weeks...........	6	8	10	11	12	13

The benefit will be paid only to employees laid off on account of slack work, not to employees discharged for other cause. No benefit will be paid after the special fund set up is exhausted. Benefits will be paid after January 1, 1933.

The fund used for the purpose of benefits will be accumulated by the concerns by laying aside up to 2 per cent of their payrolls for the year 1931 to 1932. No contributions will be made by employees during normal times. If after the plan is started and it seems to the management that the fund is inadequate, an emergency may be declared and a 1 per cent assessment made on salaries of those getting over $50 a week. In such cases the company will contribute an additional equal amount.

The description given above is not complete, but serves as a suggestion of what might be done along these lines.

The concerns in Rochester involved have studied all the questions that might arise, and any one interested in the complete layout is referred to a publication by the Industrial Management Council of the Rochester Chamber of Commerce issued on February 18, 1931. This plan may be altered in detail before it is put into effect.

All plans looking toward business recovery must include means to bring about a feeling of confidence in the minds of labor as well as of capital, and I suggest the above as a worthwhile step in that direction.

CARL L. BAUSCH.[2]

Rochester, N. Y.

TO THE EDITOR:

The program set forth by Mr. Bigelow should bring us well along the road to recovery. I quite agree with his emphasis on "adequate research." European manufacturers, it is to be observed, are keenly aware of this need. There is an increasing demand for additional products—above all, adaptation of products that have been tried and proved in the American market. Likewise American manufacturers are becoming more eager to learn from Europe. Important benefits come from this international exchange of product experience, and such an exchange is a valuable supplement to the product research carried on in each country. For example, during the past six months our European clients have sought to solve their problems of idle capacity by adding the manufacture of such varied American products as washing machines, motorcycles, automatic refrigerators, and electric clocks.

Another point which can well be emphasized is the determination of the minimum economic volume of a product. This depends on the extent of the market which the individual company decides it can best serve. In determining this market what role should export trade be given? Export has been regarded too often as a means of disposing of unplaced and irregular surpluses. Under the proposed planned management, such surpluses should disappear, and the individual company would formulate a definite long-term foreign policy, as General Motors and other large corporations have done.

In this policy consideration should be given to the needs of various foreign countries for the product, the best method of marketing the product, and the extent to which foreign countries should be supplied from the United States or from plants which would manufacture in those countries themselves.

WALLACE CLARK.[3]

TO THE EDITOR:

In MECHANICAL ENGINEERING for November last, Carle M. Bigelow says that "from now on we must reverse our basic philosophy of *producing and then selling*, to one of *selling and then producing*, in accordance with this ability to sell."

On page 96 of "Waste in Industry," 1921, I find: "The fundamental causes of waste attributable to management are: 1. The sell-then-make policy. . . ."

On page 22 of Lescohier's "Can Business Prevent Unemployment?" 1925, I quote: "The second step was one which is taken by all employers who are determined to stabilize: *the policy of making what you sell was changed to selling what you make*."

These two quotations are in direct contradiction to that by Mr. Bigelow. Possibly we should learn from the depression that excessive inventories are dangerous.

DANIEL B. LUTEN.[4]

Indianapolis, Ind.

TO THE EDITOR:

Mr. Bigelow's article on "Management Essentials for Recovery" in MECHANICAL ENGINEERING for November is most interesting and instructive, but I am afraid that Governor Roosevelt's "forgotten man" has been more than forgotten in this study of means of recovery in economic balance and prosperity. May I ask, how can business prosper if it offers only part-time employment to its workers? Is business willing to absorb through taxation the difference between earnings and livelihood?

J. Q. ADAMS.[5]

Schenectady, N. Y.

[1] H. A. Hopf and Company. Mem. A.S.M.E.
[2] Bausch & Lomb Optical Co. Mem. A.S.M.E.
[3] Consulting Management Engineer, New York and Paris. Mem. A.S.M.E.
[4] Luten Engineering Co. Mem. A.S.M.E.
[5] Research Engineer, General Electric Co. Mem. A.S.M.E.

To the Editor:

In view of the fact that the grave effects of the present depression are due to executive and management delinquencies, and not to operating shortcomings, the 40 per cent of the total of our wage earners who are the victims of the present depression should receive the first consideration.

This is a management depression due to the almost psychopathic disregard for every fundamental economic law, in the race for profits, yet the keystone of Mr. Bigelow's paper in the November issue is a solemn warning that in the future business must organize for profits.

No one has a quarrel with capital, nor with the fundamental conception of private ownership, which states that capital must have a fair return for the service it renders, but I wish to remind capital of the fact that the service must be rendered before the reward can be paid. The time has passed when capital can be considered as the preferred unit in our economic set-up, and be rewarded for service, whether performed ill or well. No matter which way we look at it, the fundamental task of capital is to provide work for the masses at large, with a steady income of real wages commensurate with the economic standard of the land. One does not have to advocate extreme economic conceptions to remind capital of the fact that the masses have a way of taking things into their own hands if current leadership fails to provide the means of existence for an extended period. Whether they would do as well as capitalistic leadership is doing today does not enter into the discussion.

In the face of these facts, to advocate organizing for profit as the *leitmotif* is, to say the least, unfortunate. We have to organize for management efficiency, competency, courage, and the maintenance of an economic responsibility so that the inexcusable blunders, mental agony, and physical suffering of the millions of American workers will never occur again. If the present industrial and financial leadership is unable to meet this obligation, they had better make room for others who will have the courage and the character to live up to these principles.

Eugene Szepesi.[6]

To the Editor:

In discussing Mr. Bigelow's most stimulating paper I should like to direct attention for a moment to certain historical aspects of the problems which it presents. Attempts at controlling the volume of production in an industry are by no means a novelty. Those of us who have read Mark Sullivan's "America Finding Herself," in his "History of Our Times," and a recent biography of a great industrialist will recall that when a new industry developed so rapidly in this country that the conditions of its' growth can, in retrospect, only be called chaos and anarchy, exactly sixty years ago a group of men attempted to bring order out of chaos by obtaining a monopolistic control of it, with a view not only of fixing prices but, incidental thereto, of controlling production. Their methods and those of their imitators, however, were so ruthless and unlawful and led directly to such abuses of power that a tremendous wave of public apprehension and indignation was aroused, leading to the passage of the Sherman "Anti-Trust" Law and other state and Federal legislation of similar tenor.

The results of this legislation we are experiencing today. The attitude of the Government—and in this attitude it has apparently reflected the feeling of the public—has been one of opposition to cooperation within the industries and, under some administrations, of definitely stimulating competition at its expense.

In his closing paragraph Mr. Bigelow notes the difficulty in the way of an individual firm's establishing, and I might add to that even of formulating, in the face of unregulated competition, policies as to volume without consideration of the other competitive units of the same industry, and he takes passing note of the obstacles which our anti-trust laws place in the way of that cooperation within the industry which would appear to be essential to the determination and establishing by an individual firm of a rational production program based upon anticipated consumption.

It would therefore appear to be high time to question whether these laws have not outlived their usefulness and should not be repealed. Of course no one familiar, however superficially, with the history of industrial development can advocate the establishment of unregulated monopolies, but, just as Government regulation has been found necessary for railroads and public utilities and, as in the case of the railroads, such regulation is leading to Governmental recommendation of consolidations under Federal control, the substitution of some such regulatory system for our industries in this second third of the twentieth century for the emotional prohibitions of the last third of the nineteenth century may appear to be salutary.

Mason A. Stone.[7]

New York, N. Y.

Debts, Booms, and Unemployment

To the Editor:

In his article on page 111 of the February issue of Mechanical Engineering Mr. D. C. Coyle says that the Federal Government can throw the burden of paying Federal debt "on wealth and thus prevent it from resting on consumer buying power." In reply, the writer would say that incomes received by the wealthy reach the market for consumption goods, if not directly, then via the workmen who construct the new capital goods in which the excess income of the wealthy may be invested.

Mr. Coyle seems much alarmed at the rising total of debt, *a la* Technocracy. Debt, however, for the most part is merely evidence of ownership. Since production has been making use of progressively larger quantities of capital goods, it is only natural that this saved wealth used to produce new wealth should belong to some one—hence the evidences of debt.

Mr. Coyle asserts that technological change "has sunk the business cycle itself." But the depression to date has not been any greater in magnitude than was indicated by the preceding degree of inflation. Mr. Coyle seems to be unwilling to admit that the period ending in 1929 was one of false prosperity engendered by inflation, and that we now face a readjustment to the prewar level of prices and the normal relationships between rent, wages, and interest.

Earlier in the same issue, Prof. S. H. Slichter discusses the problem of economic balance. In reference to this article, it seems desirable to point out that if unemployment-reserve funds are to be accumulated during booms and released during depressions, it is quite obvious that it will be necessary to have some criterion which will show when there is a boom. And if Professor Slichter has such a criterion, why permit the boom to develop until it ends in panic and depression?

If maladjustments have arisen due to an inflationary boom, payments to unemployed from an accumulated reserve can be

[6] Consulting Management Engineer. Mem. A.S.M.E.

[7] Mem. A.S.M.E.

useful in lessening the depression only to the extent that they offset the deflationary process. But eventually there will still be the readjustments to be made, and, as is quite apparent, economic necessity is the only force which will bring them about.

E. C. HARWOOD.[8]

Cambridge, Mass.

TO THE EDITOR:

Referring to Professor Harwood's comments on my article in the February issue, as far as the operation of unemployment-reserve funds is concerned, no criteria are needed to show when there are booms or depressions. Premium payments are made at all times. The funds accumulate during booms for the simple reason that at these times premium receipts exceed benefit payments. The fact that no criteria are needed for the operation of unemployment-reserve funds does not mean, of course, that they would not be useful for other purposes. Mr. Harwood, however, makes use of the expression "some criterion."

There are such differences between cycles and between the different phases of cycles that no single measure or index can tell us all that we need to know. It is necessary to have several and to use judgment in drawing inferences from them. It has been suggested that premium payments to unemployment-reserve funds be suspended during depressions. There are advantages to this, but there are disadvantages also, and, in my judgment, the latter outweigh the former.

Mr. Harwood asks, "Why permit the boom to develop until it ends in panic and depression?" Considerable can be done, as I have indicated, to limit the severity of business cycles. But the main burden of my analysis was that, although cycles can be reduced in severity, and possibly in frequency, they cannot be eliminated entirely unless we are willing to make basic changes in economic institutions—changes which would involve an abandonment of capitalism and the adoption of a form of socialism. The most important single step in reducing the severity of cycles would probably be more effective control of the expansion of credit. But, as I pointed out, even control of credit would not entirely solve the problem. The most difficult thing to control is the rate at which money is spent. I know of no feasible way to make enterprises spend in case uncertainties in the immediate future convince managers that it would be wise to defer commitments. This is precisely the difficulty confronting us at the moment. Both demand deposits and total deposits are less than 25 per cent below the level of 1929, but debits are more than 50 per cent below. In other words, the present drop in spending is attributable as much to a lower velocity of circulation as to a contraction of credit. Since it is not possible to prevent men from spending money more slowly at some times than at others, it is necessary to develop ways of offsetting the drop in spending. Unemployment reserves of the type I suggested are one way of doing this—they give purchasing power to the unemployed as soon as industry contracts its purchases of labor.

The readjustments which are necessary as a result of depression depend, in the main, upon how far demand contracts and prices drop. In so far as the operation of unemployment reserves limits the contraction of demand, it reduces the necessity for readjustments.

SUMNER H. SLICHTER.[9]

Boston, Mass.

[8] Assistant Professor, Massachusetts Institute of Technology.
[9] Professor of Business Economics, Harvard University.

A.S.M.E. Boiler Code

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Below are given records of the interpretation of the Committee in Cases Nos. 740, 745, and 749, 750, inclusive, as formulated at the meeting of February 16, 1933, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE No. 740

Inquiry: Was it the intention of the Boiler Code Committee, in revising Par. U-59 of the Code, to eliminate the use of cast-iron nozzles riveted to pressure vessels as was formerly permitted by Case No. 494? Par. U-59 specifies that materials for riveted openings shall be of rolled, forged, or cast steel.

Reply: In revising Par. U-59, the Committee overlooked the reply in Case No. 494, which indicates that the use of properly designed cast-iron nozzles riveted to air tanks is permissible. Where vessels are to be operated at working pressures not to exceed 160 lb per sq in., or at temperatures not to exceed 450 F, the Committee is of the opinion that cast-iron nozzles and fittings may be used under the Code. Riveted cast-iron fittings may be considered as reinforcement as permitted by Par. U-59b provided the thicknesses of the cast-iron parts are not less than $^5/_8$ in., and that the total area of the cast-iron reinforcement is at least twice that required for steel.

CASE No. 745

Inquiry: Will a flange which is fusion welded to a cylindrical shell or nozzle neck as shown in Fig. 29, so that at least

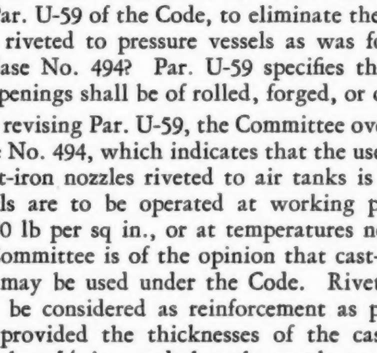


FIG. 29

nine-tenths of the depth of the flange is welded to the shell or neck, meet the Code requirements?

Reply: The Committee considers that the proposed method of connecting the flange to the shell or neck will meet the Code requirements provided (1) Class 1 welding is used for nozzles of power boilers (with the exception of the X-ray examination); (2) that Class 1 or Class 2 welding with stress

relieving is used for nozzles on unfired pressure vessels; (3) that the throat of the fillet back of the flange is not less than shown in *L* of Fig. PW-5 (P-6 of 1931 Combined Edition) or Fig. U-5; and (4) that the flange thickness is not less than specified in Table A-6. (The Committee has under consideration the requirements for flange thicknesses of sizes larger than provided for in Table A-6.)

CASE NO. 749

Inquiry: Do not the provisions of Par. U-77, which require hydrostatic testing of all welded pressure vessels, conflict with those of Par. U-64, which provide for testing by air pressure if the size is too great for the foundations to withstand the weight of the water used in testing?

Reply: It was the intent in the revision of Par. U-64 to make an exception of large fusion-welded vessels for gas-storage purposes. To provide for this it is proposed to revise Par. U-64 as follows:

U-64. *Hydrostatic Test.* Each vessel constructed under these rules shall be tested under hydrostatic pressure to not less than $1^1/_2$ times the maximum allowable working pressure. For vessels of fusion-welded construction the requirements of Par. U-77 shall apply with the following exceptions: For enameled vessels the test pressure need not exceed the working pressure; for gas-storage vessels which are too large to withstand safely the weight of the large mass of water required to fill them for hydrostatic test, they may be tested by compressed air at a pressure not to exceed the maximum allowable working pressure of the vessel.

CASE NO. 750

(Annulled)

Revisions and Addenda to the Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later in the proper place in the Code.

The following proposed revisions have been approved for publication as addenda to the Code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticism and approval from any one interested therein. Added words are printed in SMALL CAPITALS; words to be deleted are enclosed in brackets [ ]. Communications should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

PARS. P-102*i* AND U-68*i*. Replace present paragraphs by the following:

P-102*i*. For wall thicknesses of $4^1/_4$ in. and less every portion of all longitudinal and circumferential welded joints of the structure shall be examined by X-ray or gamma-ray methods of radiography. Drums or shells of a wall thickness over $4^1/_4$ in. need not be subjected to radiographic examination until such a time as evidence is submitted to the Boiler Code Committee that greater thickness can be economically examined. In order to be permitted to construct boiler drums or shells with a wall thickness over $4^1/_4$ in. without radiographic examination, a manufacturer shall have demonstrated his ability to produce sound welds in boiler drums or shells of a thickness not less than $3^1/_2$ in., the joints of which have been examined by X-ray or gamma-ray methods.

The films obtained by the use of X-rays shall be known as "exographs," and those obtained by the use of gamma rays as "gammagraphs." Both types of films shall be generally termed "radiographs."

The weld shall be radiographed with a technique which will determine quantitatively the size of defects with thicknesses equal to and greater than 2 per cent of the thickness of the base metal. To determine whether the radiographic technique employed is detecting defects of a thickness equal to and greater than 2 per cent of the thickness of the base metal, a penetrameter (universal penetration gage) of the type shown in Fig. 1 shall be placed over or alongside the weld at each

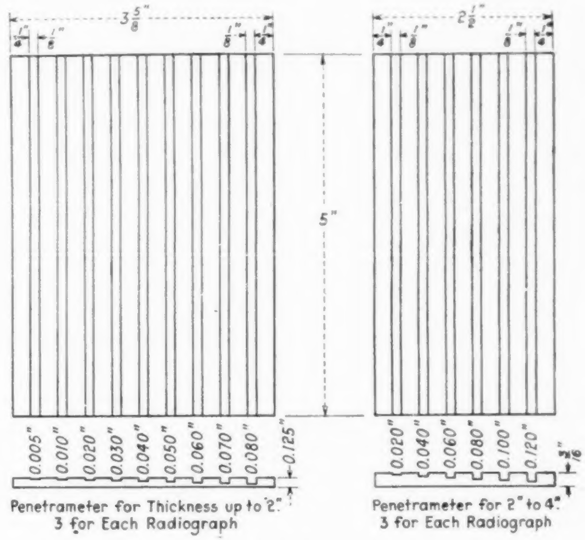


FIG. 1

end and in the center of the length of weld being radiographed during each exposure. The penetrameter shall be placed on the side of the weld next to the source of radiation. For each exposure the two end penetrameters shall be so placed that the smallest differential in the gages will coincide as closely as practicable with the ends of the section of the weld being radiographed. The images of depressions in the penetrameters, the depths of which are 2 per cent or more of the thickness of the base metal, shall be obtained on the radiograph.

The film during exposure shall be as close to the surface of the weld as is practicable. The distance of the film from the surface of the weld on the side opposite the source of radiation shall not, if possible, be greater than 1 in. With the film not more than 1 in. from the weld surface, the minimum distance between source of radiation and the back of weld shall be as follows:

Plate thickness	Minimum distance from source of radiation to back of weld
Up to 1 in.	14 in.
1 in. to 2 in.	21 in.
2 in. to 3 in.	28 in.
3 in. to 4 in.	36 in.
4 in. to $4^1/_4$ in.	38 in.

If it is necessary to expose the film at a distance greater than 1 in. from the weld, the following ratio of:

$$\frac{\text{Distance from source of radiation to weld surface toward radiation}}{\text{Distance from weld surface toward radiation to film}}$$

shall be at least 7 to 1. These conditions are imposed so as to obtain a practical maximum allowable distortion and magnification of any defects in the welded seam.

All radiographs shall be free from excessive technical processing defects which would interfere with proper interpretation of the radiograph.

Identification markers whose images will appear on the film shall be placed adjacent to the weld and their location accurately and permanently stamped near the weld on the outside surface of the drum or shell, so that a defect appearing on the radiograph may be accurately located in the actual weld.

The radiographs shall be submitted to the inspector. If the inspector requests, the following data shall be submitted with the radiographs: (1) the thickness of the base metal, (2) the distance of the film from the surface of the weld, (3) the distance of the film from the source of radiation.

The acceptability of welds examined by radiography shall be judged by comparing the radiographs with a standard set of radiographs, reproductions of which may be obtained by purchase from the Boiler Code Committee. In general the standards of judgment shall be:

1 Welds in which the radiographs show elongated slag inclusions or cavities shall be unacceptable if the length of any such imperfection is greater than $^1/_3T$, where T is the thickness of the weld. If the lengths of such imperfections are less than $^1/_3T$ and are separated from each other by at least $6L$ of acceptable weld metal, where L is the length of the longest imperfection, the weld shall be judged acceptable if the sum of the lengths of such imperfections is not more than T in a weld length of $12T$

2 Welds in which the radiographs show any type of crack or zones of incomplete fusion shall be unacceptable

3 Welds in which the radiographs show porosity shall be judged as acceptable or unacceptable by comparison with the standard set of radiographs.

The radiographs shall be retained by the manufacturer, who shall keep them on file for at least ten years.

U-68*i*. For wall thicknesses of $4^1/_4$ in. and less, every portion of all longitudinal welded joints of the structure, including the intersections with girth joints, shall be examined by X-ray or gamma-ray methods of radiography. At least 25 per cent of the length of each welded circumferential joint equally divided between not less than four uniformly spaced intervals around the circumference, shall be radiographed. Where any one radiograph fails to comply with these requirements, all parts of the circumferential seam represented by that radiograph shall be radiographed. Vessels of a wall thickness of over $4^1/_4$ in. need not be subjected to radiographic examination until such a time as evidence is submitted to the Boiler Code Committee that greater thicknesses can be economically examined. In order to be permitted to construct vessels with a wall thickness of over $4^1/_4$ in. without radiographic examination, a manufacturer shall have demonstrated his ability to produce sound welds in vessels of a thickness not less than $3^1/_2$ in., the joints of which have been examined by X-ray or gamma-ray methods.

The second, third, and fourth sections of this paragraph are identical with the corresponding sections of Par. P-102*i*.

If it is necessary to expose the film at a distance greater than 1 in. from the weld, the following ratio of:

$$\frac{\text{Distance from source of radiation to weld surface toward radiation}}{\text{Distance from weld surface toward radiation to film}}$$

shall be at least 7 to 1. These conditions are imposed so as to limit the allowable distortion and magnification of any defects in the welded seam.

The sixth, seventh, eighth, ninth, and tenth sections of this paragraph are identical with the corresponding sections of Par. P-102*i*.

PAR. P-111 AND U-79. REVISED:

P-111. (U-79.) *Distortion*. The cylinder or barrel of a drum or shell OF UNIFORM THICKNESS shall be circular at any section within a limit of 1 per cent BASED ON THE DIFFERENCE BETWEEN THE MAXIMUM AND MINIMUM DIAMETERS OF ANY SECTION, and if necessary to meet this requirement shall be reheated, rerolled, or reformed.

PAR. U-13*a*. REVISED:

U-13*a*. Plates for any part of a riveted vessel required to resist stress produced by internal pressure shall be of flange- or firebox-quality steel conforming with Specifications S-1 for Steel Boiler Plate, [and] S-2 for Steel Plates of Flange and Firebox Qualities for Forge Welding, OR S-25 FOR OPEN-HEARTH IRON PLATES OF FLANGE QUALITY of Section II of the Code, except as provided in (*b*).

PAR. U-71*a*. REVISED:

U-71. *Material*. *a* The materials used in the fabrication of any fusion-welded pressure vessel covered by this Code shall conform to Specifications S-1 for Steel Boiler Plate, S-2 for Steel Plates of Flange and Firebox Qualities for Forge Welding, [or] S-4 for Seamless Steel Drum Forgings, OR S-25 FOR OPEN-HEARTH IRON PLATES OF FLANGE QUALITY, of Section II of the Code. Shells fabricated from pipe shall conform to Specifications S-18 for Welded and Seamless Steel Pipe. The carbon content in all such material shall not exceed 0.35 per cent.

Power Test Codes

Rules for Internal-Combustion-Engine Tests

RECENTLY preliminary negotiations were completed which have resulted in the scheduling of a meeting in the United States next September of an international committee on the testing of all types of internal-combustion engines. This committee is known officially as Advisory Committee No. 19 of the International Electrotechnical Commission. The meeting will be held in the Engineering Societies' Building during the week of September 11 to 16, inclusive. It is hoped that definite agreement may be reached concerning Part I, Specification of the I.E.C. Publication on Internal-Combustion Engines. Part II, Rules for Acceptance Tests, also will be considered by the Committee at this meeting.

I.E.C. Publication on Steam Turbines Now Available

The Advisory Committee of the I.E.C. known as No. 5 on Steam Turbines, as a result of correspondence between the ten member-countries of the Committee and of meetings held in London in 1929 and in Stockholm in 1930, has finally completed two documents covering the purchase and testing of steam turbines. These are now available in pamphlet form on application to the A.S.M.E. Ask for Part I, Specification, and Part II, Rules for Acceptance Tests, of the I.E.C. Publication on Steam Turbines.

BOOK REVIEWS AND LIBRARY NOTES

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E., and the A.I.E.E. It is administered by the United Engineering Trustees, Inc., as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets, and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Forest Land in Wisconsin

Forest Land Use in Wisconsin. Report of Committee on Land Use and Forestry. Published by the State of Wisconsin, 1932. Paper, $7^3/_4 \times 10^3/_4$ in., 156 pp., 25 figs., $1.

Reviewed by Thomas D. Perry[1]

THIS survey of the Wisconsin problems of land use, including depletion of virgin timber and efforts at reforestation, is a typical example of the problem that is faced by any of the states. The Wisconsin story of timber removal may be statistically briefed as follows:

	Acres	
Original Condition (some 150 years ago):		
Virgin forests	30,000,000	
Other	5,000,000	35,000,000
Present Condition (1930–31):		
Forest lands, including cut-over	10,500,000	
Farm woodlands	5,500,000	
Agricultural land	16,000,000	
Other	3,000,000	35,000,000

It is true that one-half of the original timber land is still nominally forest land, including immense areas of cut-over lands that are relatively non-productive, as well as farm woodlands which in all probability have little real timber value.

When it comes to lumber statistics, the data presented by this booklet are as follows:

	M fbm
Original timber stand, some 150 years ago	215,000,000
Cut to date, approximately	204,000,000
Remaining stand, estimated	11,000,000
Annual growth, estimated	60,000
Annual cut (1926 basis)	900,000

This indicates that at the present rate of growth Wisconsin can rely on her own timber until about 1940 to 1945, depending upon the rapidity with which timber is converted into useful products. This, of course, may be modified by better conservation of present growing timber and a declining rate of cutting, but no extensive program of immediate reforestation can accomplish much in the meantime.

It is interesting to note that approximately only half of the Wisconsin-produced lumber is used within the state, and that the other half is exported to other states, with a corresponding import of outside lumber. This certainly affords an opportunity for intensive study of utilization that will conserve the enormous cost of transporting so large an amount of lumber back and forth across the state border lines.

The other side of the picture is that proper reforestation measures could be devised and set in motion and the lumber needs of Wisconsin industry, for perpetuity, be met on the present consumption basis as follows:

Timber for lumber (50–100-year crop)	5,000,000 acres
Timber for pulpwood (20–50-year crop)	2,000,000 acres

The report closes with an outline of a comprehensive plan for eventually restoring Wisconsin to a timber-producing basis. No argument is needed to prove the necessity of such action; in fact, the report and action ought to have been undertaken many years ago.

This report, while limited in its scope to the problems of Wisconsin, represents, with slight modifications, the identical problem that is faced by many other former timber-producing states—Michigan, New York, Pennsylvania, and Minnesota, to mention a few. Hence it is worthy of a much wider circulation and more intensive study than would ordinarily be accorded to an individual state report.

While prepared by a public-spirited and wholly non-partizan group, this report makes its appearance during a radical administration in the state, and will carry less weight than otherwise. Nevertheless, the bitter lesson of diminishing timber supplies is one that has not been sufficiently appreciated by the American public and by wood users.

[1] United Plywood Sales Corporation, New Albany, Ind. Mem. A.S.M.E.

Books Received in the Library

Aufgaben aus Technischer Mechanik Oberstufe; Höhere Festigkeitslehre, Flugmechanik, Ähnlichkeitsmechanik, Dynamik der Wellen. By L. Föppl. R. Oldenbourg, Munich and Berlin, 1932. Paper, 7 × 9 in., 106 pp., diagrams, charts, tables, 7 rm. Professor Föppl here shows, by worked-out examples, how certain advanced problems in applied mechanics may be solved. The problems considered are in the fields of the strength of materials and of dynamics. They are taken from his courses to graduate students of applied mechanics at the Munich Technical High School.

Blätter für Geschichte der Technik, No. 1. (Österreichisches Forschungsinstitut für Geschichte der Technik in Wien.) Edited by L. Erhard. Julius Springer, Vienna, 1932. Paper, 7 × 10 in., 214 pp., illus., diagrams, tables, 7.50 rm. Some twenty papers upon the history of engineering and technology are presented in this volume, the first product of the Austrian Institute for the Study of the History of Technology. These articles present some of Austria's contributions to the development of mining, engineering, manufacturing, etc. A useful bibliography on the history of Austrian technology is included.

CAR BUILDERS' CYCLOPEDIA OF AMERICAN PRACTICE, 1931. Compiled and edited for the American Railway Association—Mechanical Division. Thirteenth edition. Simmons-Boardman Publishing Co., New York, 1932. Cloth and leather, 9 × 12 in., 1260 pp., illus., diagrams, charts, tables; cloth, $5; leather, $7. This is the standard work of reference on the design, construction, and maintenance of freight and passenger cars. By means of concise descriptive articles, approved specifications, and thousands of dimensional drawings and illustrations it gives a comprehensive picture of current practice on American railroads. The new edition has been brought thoroughly up to date by deleting obsolete matter and adding developments since the edition of 1928.

DOMESTIC USES OF GAS. By A. E. Forstall and I.C.S. Staff. 82 pp., $1.50. GAS MAKING AND DISTRIBUTION. By I.C.S. Staff. Part 1, Gas Making, 71 pp.; Part 2, Gas Supply and Distribution, 47 pp., $1.85. International Textbook Co., Scranton, Pa., 1932. Cloth, 5 × 8 in., diagrams, charts, tables. These books give a useful outline of current practice in the gas industry. The treatment is descriptive and devoid of technical terms, admirably suited for beginners in the work or for those seeking general information.

EISEN- UND STAHLLEGIERUNGEN PATENTSAMMLUNG. (Supplement to Metallurgie des Eisens, in Gmelins Handbuch der Anorganischen Chemie, Eighth edition.) By A. Grützner. Verlag Chemie, Berlin, 1932. Paper, 7 × 10 in., 308 pp., tables, 32 rm. This work purports to be a complete index to the patents upon iron and steel alloys issued between 1880 and March, 1932, by the United States, England, Germany, France, Austria, and Switzerland. Over seven thousand patents are included. These are classified according to composition by a simple system. The composition, chief characteristics and uses, the name of the patentee, and the number and date of the patent are given. The book will be almost invaluable to students of alloy steels and will save many hours of searching.

FORSCHUNGSHEFT 356. GESETZMÄSSIGKEITEN DER TURBULENTEN STRÖMUNG IN GLATTEN ROHREN. By J. Nikuradse. V.D.I. Verlag, Berlin, 1932. Paper, 8 × 12 in., 36 pp., illus., diagrams, charts, tables, 5 rm. This report covers experiments at Göttingen during 1928 and 1929, under the direction of Dr. Prandtl, for the purpose of extending our knowledge of turbulent flow by experiment with very large Reynolds numbers, and of throwing light upon the relation between the Reynolds number, the law of resistance, and the velocity distribution. The results are given in full, with the conclusions deduced from them,

FORSCHUNGSHEFT 357. EIGENSPANNUNGEN IN GROSSEN SCHMIEDESTÜCKEN. By G. Kirchberg. V.D.I. Verlag, Berlin, 1932. Paper, 8 × 12 in., 29 pp., illus., diagrams, charts, tables, 5 rm. This investigation was undertaken to increase our knowledge of the internal stresses in heavy forgings, and to ascertain the adequacy of the safety factors usually assumed for forgings in the construction of machinery. The internal stresses in two heavy forgings were accurately determined by experiment, the methods and results being reported in full.

DAVISON'S KNIT GOODS TRADE, 42nd edition, September, 1932. Leather, 7 × 9 in., 748 pp., illus., maps, office edition, $6; pocket edition, $5.

DAVISON'S TEXTILE BLUE BOOK, United States, Canada, and Mexico. 67th year. Leather, 5 × 8 in., 1322 pp., illus., maps, office edition, $7.50; handy edition, $5; salesmen's edition, $4. Publ. by Davison Publishing Co., New York. These directories list and cross index the entire industries from dealers in raw materials and manufacturers through agents to wholesalers and buyers. Full information is given upon the officers, capitalization, capacity, and products of mills, as well as upon other matters of interest to buyers and sellers. The directories are the result of long experience and are thoroughly adequate.

KURBELWELLEN MIT KLEINSTEN MASSENMOMENTEN FÜR REIHENMOTOREN. By H. Schrön. Julius Springer, Berlin, 1932. Paper, 8 × 11 in., 66 pp., diagrams, charts, tables, 16.50 rm. An extended mathematical investigation of the balancing of internal-combustion engines is presented. The examination covers engines with from two to twelve cylinders, including all two-cycle engines and all four-cycle engines with an odd number of cylinders. The most favorable balance for each case is determined.

MECHANICAL TESTING. Vol. 1. Testing of Materials of Construction. (D. U. Technical Series.) By R. G. Batson and J. H. Hyde. Second edition. E. P. Dutton & Co., New York, 1931. Cloth, 6 × 9 in., 465 pp., illus., charts, diagrams, tables, $6.50. This work is intended to inform engineers, manufacturers, and students concerning the conditions that govern the testing of structural materials, to give them particulars about the standard testing plant and its limitations, and to provide information that will enable them to interpret correctly the results of tests. The new edition has been revised to conform with the specifications of the British Engineering Standards Association, and the chapters on fatigue and hardness testing and testing at high temperatures have been enlarged. The field is covered comprehensively and thoroughly.

MITTEILUNGEN DES HYDRAULISCHEN INSTITUTS DER TECHNISCHEN HOCHSCHULE MÜNCHEN. No. 5. By D. Thoma. R. Oldenbourg, Munich and Berlin, 1932. Paper, 8 × 11 in., 67 pp., illus., diagrams, charts, tables, 4.60 rm. This number contains: a method for reducing the influence of turbulence upon the accuracy of current meters; an investigation of the effect of the viscosity of water upon the hydraulic properties of a small model Francis turbine; tests of the lubricating value of oils; and an investigation of the losses of circular pipe elbows with angles of less than ninety degrees.

NEXT OIL POOL. By W. R. Jillson. Transylvania Press, Lexington, Kentucky, 1932. Cloth, 5 × 8 in., 116 pp., illus., maps, $2.50. The object of Dr. Jillson's book is to call attention to new areas in Kentucky which give promise of producing large amounts of petroleum. He has excluded from consideration the fully developed areas and also those which extensive drilling has proved to be of little value. Thirteen districts remain, which are described very briefly.

TECHNICAL DATA ON FUEL. Edited by H. M. Spiers. Third edition. British National Committee of the World Power Conference, London, 1932. Leather, 5 × 8 in., 302 pp., diagrams, charts, tables, 12s. 6d. (Obtainable from American Committee, World Power Conference, 1419 Chrysler Building, New York, $2.75.) This handy collection of tables and charts, with explanatory notes, is intended to provide those working with fuel problems with some of the information which they constantly require and which is not readily available. The information covers a wide range and the data have been carefully chosen. The fact that three editions have been issued within four years shows that the book fills a need.

TECHNISCHE KULTURDENKMALE IM AUFTRAG DER AGRICOLA-GESELLSCHAFT BEIM DEUTSCHEN MUSEUM. By C. Matschoss and W. Lindner. Verlag F. Bruckmann A.-G., Munich, 1932. Cloth, 9 × 12 in., 127 pp., illus., $1.65 (Stechert). Brief essays upon the evolution of engineering, accompanied by a remarkable series of photographs of specimens of early bridges, machines, workshops, etc., which are still in existence in Germany. An attractive work, of considerable historic interest.

TESTING OF HIGH SPEED INTERNAL COMBUSTION ENGINES. By A. W. Judge. Second edition. D. Van Nostrand Co., New York, 1932. Cloth, 6 × 9 in., 459 pp., illus., diagrams, charts, tables, 25s. The aim of this book is to provide engineers and manufacturers with a treatise, neither too elementary nor too advanced, which presents the basic principles of engine testing and describes the apparatus and methods generally used. Advanced workers and research engineers in search of a general survey will also find it useful. In this new edition recent developments have been added and modern methods and equipment substituted for obsolete ones.

TIME AND MOTION STUDY. By S. M. Lowry, H. B. Maynard, and G. J. Stegemerten. Second edition. McGraw-Hill Book Co., New York, 1932. Cloth, 6 × 9 in., 471 pp., illus., diagrams, charts, tables, $5. The volume, based upon the experience of the Westinghouse Electric and Manufacturing Company, is intended to be a textbook and also a handbook for factory executives and practical men. Methods of time study are described in detail, and directions given for constructing formulas from time studies. The organization and supervision of time-study, formula, and wage-payment work in a plant is outlined. In the new edition greater emphasis is placed upon motion study, its methods being described in detail and formula examples added for several new kinds of work.

TIN SOLDERS. By S. J. Nightingale. British Non-Ferrous Metals Research Association, London, 5s; Chemical Catalog Co., New York, 1932. Cloth, 5 × 8 in., 89 pp., illus., diagrams, charts, tables, $1.50. The essential properties of solders have been known and utilized for centuries, but our knowledge of their exact metallurgy and systematic study of their mechanical properties are quite recent developments. In the present book the results of modern study are summarized, with special reference to the needs of users of solders. The composition and physical properties of the solder alloys and the strength of soldered joints are discussed, with directions for making sound joints and for choosing solders for different purposes.

TURBINEN UND PUMPEN, THEORIE UND PRAXIS. By F. Lawaczeck. Julius Springer, Berlin, 1932. Cloth, 6 × 9 in., 208 pp., illus., diagrams, charts, tables, 22.50 rm. For twenty years Dr. Lawaczeck has been actively engaged in the development of the turbo-pump and the propeller turbine, the final result being the turbine that bears his name. In this book he gives an interesting account of the researches, both theoretical and practical, which were carried out during the period of development, and of the commercial machines that resulted.

UNTERSUCHUNGSMETHODEN FÜR ROHEISEN, STAHL UND FERROLEGIERUNGEN. (DIE CHEMISCHE ANALYSE, Vol. 31.) By J. Kassler. Ferdinand Enke, Stuttgart, 1932. Paper and bound, 7 × 10 in., 158 pp., diagrams, tables; paper, 17.80 rm.; bound, 19.60 rm. A manual for the steel-works laboratory, containing selected methods for the analysis of iron and steel and the iron alloys used in making alloy steels. All the usual determinations are included, a few methods, carefully chosen for accuracy and rapidity, being given for each. The directions are brief, yet clear. The author writes from long experience in the analysis of alloy steels.

WERKSTOFFHANDBUCH NICHTEISENMETALLE. Nachtrag IV. By Deutsche Gesellschaft für Metallkunde. Beuth-Verlag, Berlin, 1932. Paper, 6 × 8 in., 6 sheets, illus., diagrams, charts, tables, 2.60 rm. This supplement appears in loose-leaf form, ready for insertion in the handbook. Six articles are included: shearing tests, by G. Fiek; resistance to corrosion of copper, by P. Siebe; recrystallization of brass, by K. Ewig-Daues; aluminum foil and its uses, by F. Thomas; riveting light alloys, by H. Bohner; and melting furnaces for non-ferrous metals, by G. Mannigel.

ZERSPANBARKEITSUNTERSUCHUNGEN MIT SPIRALBOHRERN. (Berichte über betriebswissenschaftliche Arbeiten, Vol. 8.) By A. Wallichs, H. Beutel, and W. Mendelson. V.D.I. Verlag, Berlin, 1932. Paper, 9 × 12 in., 32 pp., illus., diagrams, charts, tables, 5.20 rm. These are reports of carefully planned investigations of the drilling properties of cast iron and cast steel, undertaken to determine the laws governing their machinability and to obtain practical working factors. The first report considers the cutting forces and edge-keeping qualities of spiral drills in relation to clearance, diameter, web relief, etc., and the drilling properties of various cast steels. The second treats of cast irons in like manner. The third presents equations for cutting forces and usable cutting speeds, based on the results of these tests, and charts from which the maximum cutting speed for any material and feed can be read.

NOTE: The price of "The Development of American Industries," by John G. Glover and William B. Cornell, published by Prentice-Hall, Inc., New York, has been changed from $5 to $6. This book was reviewed by Carle M. Bigelow in the January issue of MECHANICAL ENGINEERING.

WHAT'S GOING ON

Engineering Week at Chicago Exposition

ENGINEERING WEEK at the Century of Progress Exposition, Chicago, June 25 to July 1, will be the occasion for the Semi-Annual Meeting of The American Society of Mechanical Engineers, as well as meetings of many other national engineering societies. Plans are being laid for a program of technical and social events that will rival in size and interest one of the Society's Annual Meetings.

At present writing upward of 40 technical sessions have been planned, as follows: five on aeronautics, three on printing industries, three on machine-shop practice, four on fuels, three on iron and steel, one on materials handling, two on management, four on applied mechanics, four on hydraulics, one on railroads, two on process, three on power, three on wood industries, one on education and training, and two on research.

Because of the meetings being held by other engineering societies during this same week, a number of joint sessions will be held. For example, the Applied Mechanics Division will meet with the Structural Division of the American Society of Civil Engineers, and the Hydraulic Division is to have a joint program with the Power Division of the same society.

Among the other engineering societies meeting in Chicago during the week are the American Society of Civil Engineers, with headquarters at the Palmer House; the American Institute of Electrical Engineers, with headquarters at Edgewater Beach Hotel; the American Institute of Mining and Metallurgical Engineers, with headquarters at the Stevens Hotel, where also the American Society for Testing Materials will meet; and the Society for the Promotion of Engineering Education. The American Association for the Advancement of Science meets the preceding week.

As announced last month, Wednesday, June 28, will be Engineers' Day, on which there will be a joint inspection of the Exposition by all the engineering societies, the day's proceedings culminating in a banquet. No technical sessions have been scheduled for this day.

Accommodations for members of the A.S.M.E. have been assured by tentative reservations at the Palmer House, which will be the Society's headquarters and the scene of its technical sessions.

Annual Report of the Engineering Foundation

THE 1932 Annual Report of The Engineering Foundation calls attention to its work during the past year. Arch dams for water supply, power development, flood control and irrigation, and steel columns for buildings and bridges were the subjects of two researches completed. The Iron Alloys Committee published the first book in its series on the combination of iron and steel with other substances, "The Alloys of Iron and Molybdenum." A guidance pamphlet, "Engineering: a Culture—a Career," resulted from the efforts of the Education Research Committee, of which Dr. Harvey N. Davis was chairman.

Subjects of other researches aided by the Foundation, and progressing in many parts of the country, include concrete arches for bridges; earths and foundations; centrifugal apparatus for testing mining excavation methods; models of structures and specimens of materials; boiler feedwaters; critical-pressure steam boiler; effects of temperature on metals; cutting of metals; lubrication of machines and cars; electric welding; and the plastic flow of concrete under the pressures existing in large bridges, dams, and other structures.

Educational courses were organized by the Foundation at the close of 1932 for engineers temporarily without engagements because of business conditions. At present these cover power-plant engineering, business finance (special), mechanical equipment of buildings, industrial applications of electricity, sales engineering (special), and industrial management. No charge is made. Supervision of the courses has been assumed by Columbia University, New York University, Polytechnic Institute of Brooklyn, and Stevens Institute of Technology, and rooms are provided in the Engineering Societies Building by United Engineering Trustees, Inc. The courses began in January and will continue to the end of May.

The Engineering Foundation, which is the research department of the United Engineering Trustees, Inc., was established in 1914 on the basis of suggestions and a gift by Ambrose Swasey "for the furtherance of research in science and in engineering." The chairman for 1932 was H. Hobart Porter, member A.S.M.E. A.S.M.E. representatives were Edwards R. Fish, Albert E. White, and D. Robert Yarnall.

Officers of Engineering Foundation for 1933

AT THE annual meeting of the Engineering Foundation, held on February 16, the following officers were elected to serve until the annual meeting February 15, 1934: Chairman, George W. Fuller; first vice-chairman, H. P. Charlesworth; second vice-chairman, H. C. Bellinger; members of executive committee, D. Robert Yarnall and J. V. N. Dorr. Alfred D. Flinn was reappointed director and secretary.

U.E.T. President's Report for 1932

IN HIS report as president of the United Engineering Trustees, Inc., the organization which administers the affairs of the Engineering Societies Building, headquarters in New York for the Founder Societies, H. A. Kidder commented upon its financial affairs as follows:

"Assets for which the corporation is responsible (real estate at cost, 'funds' at book value, and Library as appraised) total nearly four million dollars. All departments closed the year without deficits. The income of the Administrative Department was $2329.60 less than predicted in the budget, and the expenditures for all purposes were $18,295.11 less. This latter amount included, however, a reduced allotment of $6000 to the Depreciation and Renewal Fund, held in suspense, and a provision of $4000 for operating, each to start the new year. There was thus a net saving of $8295.11 as part of the financial program for the period July 1, 1932, to December 31, 1933, adopted by the Board of Trustees in June, 1932. The General Reserve Fund was $6065.60 less than the established amount, $10,000, and the Depreciation and Renewal Fund was $12,000 less than it should have been December 31, 1932; both should be restored from general income as soon as practicable.

"The total book value of all the funds for which United Engineering Trustees, Inc., is responsible is $1,394,355.40. The market value as of December 31, 1932, was $1,102,-741.88. The cumulated shrinkage of that date was $291,613.52, or 21 per cent."

A.S.M.E. representatives on the U.E.T. for 1932 were F. A. Schaff, H. V. Coes, and Edwards R. Fish.

Air-Conditioning Conference of San Francisco Section

AIR conditioning is a new industry of national interest, but with local problems which require local consideration. With this in mind, arrangements were made by the San Francisco Section of the A.S.M.E. for a Western Conference on Air Conditioning, which was held at the University of California, Berkeley, on February 9 and 10 and well attended. Dr. Baldwin M. Woods, Dean of the School of Mechanical Engineering of the University, served as chairman.

The following papers were presented: In "The Basic Theory of Air Conditioning," by Prof. L. Washington, the author discussed properties of air, showing how we are able to "manufacture" our own weather. "The Psychrometric Chart" was developed by C. R. Dodson, showing how one curve is related to the others. Dr. C. W. Brown spoke on the "Physiological-Psychological Basis of Comfort," explaining the *why* of comfort. Lee Hungerford, chief engineer of the Fox West Coast Theatres, presented valuable data relative to the reactions of audiences to conditioned air in his paper, "What Is Comfort?"

"An Analysis of Cooling Fundamentals" was presented by Prof. Walter S. Weeks, and was followed by a paper on "Cooling With Ice in California Valley Summer Weather," by H. L. Lincoln, which described an installation in Stockton, Calif. "Insulation and Heat Capacity in Relation to Heat Transfer," by Prof. L. M. K. Boelter, proved extremely interesting because of the relation of the subject to heating and cooling. "An Analysis of Los Angeles Weather," by Lester J. Rich, showed what can be learned from weather-bureau reports.

"Design Procedure for Heating and Cooling Installations," by W. E. Leland; "Air Filtration," by F. W. Kolb; "Air Infiltration Through Windows," by V. H. Cherry, and the "Architect's Problems in Heating, Cooling, and Ventilating," by J. J. Donovan, were the papers of another group. The final session comprised papers on "Control and Regulation," by T. B. Hunter; "Cooling Rural Homes," by Dr. B. M. Woods and Associates; and one by Prof. E. K. Strong on "The Psychology of Selling."

These papers have been published in book form, copies of which may be obtained from A. P. Hahn, 16 California St., San Francisco, Calif., at $1 each, check or other form of remittance to accompany order.

Coming Meetings of A.S.M.E. Local Sections

Buffalo: April 3. Hotel Statler, Buffalo, N. Y., at 8:00 p.m. Subject: Present-Day Economics, by Ralph E. Flanders, Jones & Lamson Machine Tool Company, Springfield, Vt., and former Vice-President of the A.S.M.E.

Cleveland: April 5. Joint Meeting with the Cleveland Engineering Society, Rooms of the Cleveland Engineering Society, 410 Hanna Building, Euclid Ave. at E. 14th St., Cleveland, Ohio. Subject: Present-Day Economics, by Ralph E. Flanders.

Erie: April 4. Subject: Present-Day Economics, by Ralph E. Flanders.

Metropolitan: April 5. Engineering Societies Building, Room 1101, 29 West 39th St., New York. Meeting to be sponsored by the A.S.M.E. Management Division.

April 14. Engineering Societies Building, Room 1101. Meeting to be sponsored by the A.S.M.E. Petroleum Division.

April 18. Engineering Societies Building, Room 502. Meeting to be sponsored by the A.S.M.E. Applied Mechanics Division.

April 19. Engineering Societies Building, Room 1101. Meeting to be sponsored by the A.S.M.E. Management Division.

April 20. Engineering Societies Building, Room 501. Meeting to be sponsored by the A.S.M.E. Power Division.

Milwaukee: April 24. Evening Meeting of the Section. Dean A. A. Potter, President of the A.S.M.E., will address the members and guests.

Minneapolis: April 25. Joint dinner meeting with the A.S.M.E. St. Paul Section. Dean A. A. Potter, President of the A.S.M.E., will address the members and guests.

New Haven: April 19. Yale University, Mason Laboratory at 8:00 P.M. Subject: Ships That Do Not Roll, by Professor Herbert L. Seward, Yale University.

Oregon: April 22. Oregon State College, afternoon and evening. Joint Meeting with the Student Branch. Subject: Non-ferrous Metals, by Charles E. Thomas, associate professor; Mechanics and Materials, Oregon State College, Corwallis, Ore., and by C. R. Boyle, Aluminum Company of America.

Rock River Valley: April 28. Rockford, Ill. Dean A. A. Potter, President of the A.S.M.E., will address the members and guests at this meeting.

St. Paul: April 25. Joint Dinner Meeting with the Minneapolis Section. Dean A. A. Potter, President of the A.S.M.E., will address this meeting.

Tri-Cities: April 26. Davenport, Iowa. Dean A. A. Potter, President of the A.S.M.E., will address the members and guests at this meeting.

Western Washington: April 20. The Commons, University of Washington, at 6:30 p.m. Subject: Student papers on thesis work.

Candidates for Membership in the A.S.M.E.

The application of each of the candidates listed below is to be voted on after April 25, 1933, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references.

NEW APPLICATIONS

BLOOM, K. E., Oakland, Calif.
EISENMANN, R. C., Chicago, Ill.
FRASER, O. B. J., New York, N. Y.
GAUSS, CHESTER A., New York, N. Y.
GLASS, STEPHEN K., Mt. Carmel, Pa.
HANN, HOWARD J., Mt. Carmel, Pa. (Rt)
HEINTZ, CHAS. E., New York, N. Y.
HINKEL, O. R., New York, N. Y.
HOPKINS, SIDNEY L., Ansonia, Conn.
JENSEN, J. O., Los Angeles, Calif.
JOHNSON, CHAS. A., Angola, Ind.
KNAPP, VERNON W., New York, N. Y.
MAYHEW, BENJAMIN ALAN, Tenafly, N. J.
MCCAMMOND, WALTER W., L. I. City, N. Y.
MCKEE, NORMAN C., Redwood City, Calif.
NEE, JOS. C., Albuquerque, N. M.
NEWMAN, PAUL F., North Plainfield, N. J.
NORTON, PAUL T., Blacksburg, Va.
PERRY, AL BENJAMIN, Pittsburg, Calif.
PHILLIPS, S. H., Oakland, Calif.
POLK, G. C., Detroit, Mich.
QUIER, KENNETH E., Brooklyn, N. Y.
RICKARD, HENRY C., Bradford, Mass.
ROGERS, GEO. A., Dobbs Ferry, N. Y.
SAMUT, E. J., New York, N. Y.
SIEGER, EUGENE K., Elmhurst, L. I., N. Y.
SMITH, DONALD A., Brooklyn, N. Y.
TEMPLETON, WM., Orange, N. J.
TILLQUIST, DAVID, New York, N. Y.

CHANGE OF GRADING

Transfers from Associate-Member:
FISHER, WM. J., York, Pa.
FREUND, CLEMENT J., Detroit, Mich.
HALL, R. BENSON, Chicago, Ill.
TOOLE, GERALD C., St. Albans, L. I., N. Y.
Transfers from Junior:
BAILEY, JAS., Hamburg, N. Y.
BARKER, VIRGIL D., New York, N. Y.
CAMERON, C. E., JR., Newark, N. J.
EVOY, MARTIN, Abington, Pa.
HARRINGTON, G. G., Houston, Tex.
MADEHEIM, HUXLEY, New York, N. Y.
NIEMEYER, EDW. A., Crestwood, N. Y.
NORRIS, NELSON H., New York, N. Y.
PFEFFERLE, FRANK H., Cincinnati, Ohio
RUNYON, MALCOLM E., Newark, N. J.
SEARS, HAROLD THOMPSON, Bartlesville, Okla.